LAW OFFICES

JENNER & BLOCK

A PARTNERSHIP INCLUDING PROFESSIONAL CORPORATIONS

ONE IBM PLAZA
CHICAGO, ILLINOIS 60611

(312) 222-9350
(312) 527-0484 FAX

WASHINGTON OFFICE
21 DUPONT CIRCLE, N.W.
WASHINGTON, D.C. 20036
(202) 223-4400
(202) 223-6058 FAX

LAKE FOREST OFFICE
ONE WESTMINSTER PLACE
LAKE FOREST, IL 60045
(708) 295-9200
(708) 295-7810 FAX

MIAMI OFFICE
ONE BISCAYNE TOWER
MIAMI, FL 33131
(305) 530-3535
(305) 530-0008 FAX

GRACE KOH ANGELOS

November 15, 1990

Ms. Cathy O'Connell
Project Manager
Site Response Section
Ground Water and Solid Waste Division
Minnesota Pollution Control Agency
520 Lafayette Road
St. Paul, Minnesota 55155

Re: Requirement to Provide Information
<u>Pig's Eye Dump/Fish Hatcheries Dump</u>

Dear Ms. O'Connell:

Jenner & Block represents CMC Heartland Partners ("Heartland"). Heartland hereby responds to the Minnesota Pollution Control Agency's ("MPCA") Requirement to Provide Information ("RPI") addressed to CMC Real Estate Corporation ("CMC Real Estate").

CMC Real Estate was dissolved on December 11, 1989, and thus, is no longer in existence.

Through a series of corporate transactions, CMC Real Estate's ownership interest in a 177-acre parcel (hereinafter referred to as the "Railroad Parcel") was conveyed to Heartland. The Railroad Parcel and the adjoining property owned by the City of St. Paul, comprise Pig's Eye Dump. The Railroad Parcel is the same property which was owned by the Chicago, Milwaukee, St. Paul & Pacific Railroad Company ("Railroad") and leased to the City of St. Paul for use as a landfill. Attached as Exhibit A is a map outlining in black the Railroad Parcel.

As a recent purchaser of the Railroad Parcel, Heartland is responding to the RPI addressed to CMC Real Estate.

Heartland's responses to the RPI are set forth below. Where appropriate, documents are included herewith in response to MPCA's requests for production.

GENERAL OBJECTION

Heartland objects to this RPI to the extent that the subject site of the RPI -- Pig's Eye Dump/Fish Hatcheries Dump -- encompasses two distinct, separate and non-contiguous facilities. Neither Heartland nor its predecessors have had any ownership interest or involvement with the Fish Hatcheries Dump. Moreover, Heartland and its predecessors only owned a portion of the Pig's Eye Dump as described above. Accordingly, unless specified otherwise, Heartland's responses to the RPI will be limited to information relating to the Railroad Parcel.

REQUEST NO. 1

Identify the full legal name, address and phone number of the business or governmental entity, hereinafter referred to as "business."

RESPONSE NO. 1

The "business" is identified as follows:

CMC Heartland Partners, a Delaware general partnership
547 West Jackson Blvd.
Chicago, Illinois 60606
(312) 822-0400

Heartland's business involves the ownership, operation, financing, leasing, management, sales and development of real estate and other properties and interests.

REQUEST NO. 2

How many years has the business been in operation?

RESPONSE NO. 2

Although Heartland was formed on October 27, 1988, it was not in operation until it purchased through a series of corporate transactions substantially all of CMC Real Estate's real estate assets on June 27, 1990. Accordingly, Heartland has been in operation for approximately four months.

REQUEST NO. 3

Identify the names and current addresses and telephone numbers of all current and past owner(s) of the business.

RESPONSE NO. 3

The current owner(s) of the business are as follows:

Milwaukee Land Company, an Iowa corporation
547 West Jackson Blvd.
Chicago, Illinois 60606
(312) 822-0400

Heartland Partners, L.P., a Delaware limited partnership
547 West Jackson Blvd.
Chicago, Illinois 60606
(312) 822-0400

The parties listed above have been the owners of Heartland since its formation in 1988.

REQUEST NO. 4

Provide a map indicating that portion of the site(s) owned or operated by the business. Include leases.

RESPONSE NO. 4

Heartland hereby reasserts its General Objection. Without waiving this objection, attached as Exhibit A is a map which shows in black outline the portion of the Pig's Eye Dump owned by Heartland. The area outlined in pink was leased to the City by the Railroad, the owner at the time, pursuant to a License dated May 1, 1957 ("Lease No. 65235"). Lease No. 65235 was superseded by a License dated August 19, 1958 between the Railroad and the City ("Lease No. 66368") for the use of the same area outlined in pink.

The area outlined in black was leased to the City by the Railroad pursuant to an Agreement dated November 6, 1962 ("Lease No. 69895"). Lease No. 69895 was terminated by agreement of the Railroad and the City on November 24, 1978, with the termination to be effective as of January 1, 1978.

Pursuant to an Indenture dated March 1, 1978, between the Railroad and the City ("Lease No. 82316), Lease No. 66368 was modified to enlarge the area leased to the City to the area outlined in red. Lease No. 82316 was terminated by agreement of the Railroad and the City on November 26, 1980, with the termination to be effective as of January 1, 1980.

Pursuant to the terms of these leases, the City is responsible for any costs which may be incurred in the cleanup of the Railroad Parcel. Copies of Lease Nos. 65235, 66368, 69895, and 82316 are attached hereto as Exhibit B.

REQUEST NO. 5

Identify all MPCA, Minnesota Department of Health and other environmental permits issued by Federal, State, county, city or other governmental authorities that the business holds and the effective dates for such permits.

RESPONSE NO. 5

Heartland hereby reasserts its General Objection. Moreover, Heartland objects to this Request No. 5 because it is vague and overly broad. Without waiving these objections, Heartland states that because the Pig's Eye Dump was operated by the City of St. Paul, Heartland does not have any permits relating to the site. Moreover, neither Heartland nor its predecessors in the past had any permits relating to the site.

REQUEST NO. 6

Identify and list all businesses and industrial customers whose garbage and/or hazardous wastes or pollutants or contaminants were placed at the site(s). Include waste characterization, volume, dates, and current business contacts (if known).

RESPONSE NO. 6

Heartland reasserts its General Objection. Without waiving this objection, Heartland states that because Heartland did not operate the Pig's Eye Dump, it does not have access to comprehensive information relating to the identity of customers who placed garbage and/or hazardous wastes or pollutants or contaminants at the site. Heartland has, however, in the past obtained a limited number of documents from the City of St. Paul, the operator of the Pig's Eye Dump, and from the MPCA. In reviewing these documents, we have discovered the names of parties that may have been customers at the Pig's Eye Dump. A list of these parties and related information from the City's and MPCA's records are included in Exhibit C.

The operations of the Railroad which generated the limited amount of Railroad waste (as described in Exhibit C) placed at the Pig's Eye Dump are now owned by the Soo Line Railroad Company ("Soo Line"), Soo Line Building, Minneapolis, Minnesota 55440. As part of that purchase, the Soo Line acquired the Railroad's liabilities related to those operations. Because the Railroad is no longer in existence, there is no current business contact for the Railroad.

The Soo Line acquired the liabilities associated with the rail assets as part of the Railroad's bankruptcy reorganization. On December 19, 1977, the Railroad filed its petition to effect a plan of reorganization under Section 77 of the United States Bankruptcy Act of 1988, as amended. Pursuant to Order No. 809 of the United States District Court for the Northern District of Illinois, Eastern Division (the "Reorganization Court"), the Railroad was partitioned into a rail division and a real estate division. The rail division was sold to the Soo Line on February 19, 1988. With this sale to Soo Line, the Railroad got out of the railroad business. Thus, the Railroad's liabilities and obligations, if any, relating to the rail activities at the Pig's Eye Dump may be the responsibility of the Soo Line.

On July 12, 1985, the Reorganization Court entered an order ("Order No. 832") approving and confirming a Plan of Reorganization ("Plan"). The Reorganization Court established a bar date of January 9, 1980 for pre-petition claims and a bar date of September 10, 1985 for post-petition claims. On or before August 31, 1979, notice of the filing of the creditors list was given to the State of Minnesota. Thereafter, on July 22, 1985, a Notice of Bar Dates for Claims was served on the State of Minnesota. Minnesota brought no claims relating to Pig's Eye Dump before either of the bar dates.

Pursuant to the Final Decree of the Reorganization Court dated November 12, 1985 ("Order No. 866"), CMC Real Estate, as the reorganized company, was vested with all of the bankruptcy trustee's right, title and interest in the remaining property of the Railroad's estate, which included the Railroad Parcel, "free and clear of all claims, rights, demands, interests, liens and encumbrances of every kind and character." (See Order No. 866, p. 7.) The Plan and Order Nos. 809, 832 and 866 are attached as Exhibit D.

CMC Real Estate came into possession of the Railroad Parcel free and clear of all claims, including any claims which may result from the Railroad's ownership of the Railroad Parcel. Thus, CMC Real Estate is not responsible for any costs which may arise as a result of the conditions on the Railroad Parcel. Because Heartland is a successor in interest to CMC Real Estate, Heartland also owns the Railroad Parcel free and clear of all claims.

REQUEST NO. 7

Identify and list all transporters of garbage and/or hazardous wastes or pollutants or contaminants that were placed at the site(s). Include waste characterization, volume, dates, and current business contacts (if known).

RESPONSE NO. 7

Heartland hereby reasserts its General Objection. Without waiving this objection, Heartland states that because neither Heartland nor its predecessors operated the Pig's Eye Dump, Heartland does not have access to comprehensive information relating to the identity of transporters of garbage and/or hazardous wastes or pollutants or contaminants that were placed at the site.

Heartland has, however, in the past obtained a limited number of documents from the City of St. Paul, the operator of the Pig's Eye Dump. In reviewing these documents, we have discovered the name of the following party which may have transported garbage to the Pig's Eye Landfill for the Railroad: Twin City Waste Disposal. (See Exhibit E.) Heartland lacks information regarding the address or current business contact of Twin City Waste Disposal. Roy Johnson, a former employee of the Railroad, has advised Heartland that Twin City Waste Disposal did not transport any hazardous wastes, contaminants or pollutants to the Pig's Eye Dump for the Railroad.

REQUEST NO. 8

Provide a map indicating the portions of the site(s) dedicated to specific uses or specific businesses.

RESPONSE NO. 8

Heartland hereby reasserts its General Objection. Without waiving this objection, Heartland has attached as Exhibit F, a map showing an area leased to the City of St. Paul for a landfill (outlined in black), an area leased to the City of St. Paul for the disposal of diseased trees (outlined in green), and an area leased to the City of St. Paul for the disposal of explosives (outlined in red).

REQUEST NO. 9

How was the garbage and/or hazardous wastes or pollutants or contaminants picked up from businesses or industrial customers stored (e.g., in drums, barrels, dumpsters) for pick up? For transport?

RESPONSE NO. 9

Heartland hereby reasserts its General Objection. Without waiving this objection, Heartland states that through its interview of Mr. Roy Johnson, it has discovered that the Railroad used containers of varying size to collect garbage. These containers were picked up by different waste haulers, and transported to and emptied at the Pig's Eye Dump. Other than Twin City Waste Disposal, Heartland does not know the identity of other waste hauler which may have been used by the Railroad or any of the other customers of the Pig's Eye Dump.

REQUEST NO. 10

How was the garbage and/or hazardous wastes or pollutants or contaminants disposed of (e.g., drums buried or emptied and returned) at the site(s)?

RESPONSE NO. 10

See Response No. 9.

REQUEST NO. 11

Identify all persons whom the business consulted in the preparation of the response to the Questionnaire, including their current addresses and telephone numbers and relationship to the business.

RESPONSE NO. 11

Heartland consulted the following persons in preparing the response to the Questionnaire:

Jack Bauer
Senior Draftsman
CMC Heartland Partners
547 W. Jackson Blvd.
Chicago, IL 60606
(312) 294-0473

Gerald Johnson
Lease Supervisor
CMC Heartland Partners
547 W. Jackson Blvd.
Chicago, IL 60606
(312) 294-0470

Joseph Mariano
Area Manager
CMC Heartland Partners
547 W. Jackson Blvd.
Chicago, IL 60606
(312) 294-0449

Edward Noftz
Manager of Contracts and Support Services
CMC Heartland Partners
547 W. Jackson Blvd.
Chicago, IL 60606
(312) 294-0478

Ray Lamberty
Vice President of Sales and Property Management
CMC Heartland Partners
547 W. Jackson Blvd.
Chicago, IL 60606
(312) 294-0466

Lawrence S. Adelson
Vice President and General Counsel
CMC Heartland Partners
547 W. Jackson Blvd.
Chicago, IL 60606
(312) 294-0471

Roy Johnson
Former Divisions Engineer
Chicago, Milwaukee, St. Paul & Pacific Railroad Company
10301 10th Avenue Circle
Bloomington, MN 55420
(612) 881-2274

Charles Harrison
Counsel
CMC Heartland Partners
547 W. Jackson Blvd.
Chicago, IL 60606
(312) 294-0488

Robert Yurshak
Consultant
5623 West Cortland
Chicago, IL 60639
(312) 889-6336

REQUEST NO. 12

Identify any other persons who may be able to provide a more detailed or complete response to the Questionnaire or who may be able to provide additional relevant documents.

RESPONSE NO. 12

The following party may be able to provide a more detailed or complete response to the Questionnaire:

City of St. Paul
Department of Public Works
234 City Hall & Court House
St. Paul, Minnesota 55102.

Metropolitan Waste Control Commission
350 Metro Square Building
St. Paul, MN 55101

The following party may be able to provide relevant documents relating to the Railroad's placement of garbage at the Pig's Eye Landfill:

Soo Line Railroad Company
Soo Line Building
Minneapolis, MN 55440.

No response to any of these requests is intended to be an admission that MPCA is lawfully entitled to the information as requested, or that any particular action by Heartland subjects it to any statutory, regulatory or other requirement.

The above written statements are submitted under the notarized signature of a duly authorized official certifying that Heartland has made a diligent search of its records and has conducted a diligent interviewing process in connection with the information request. Although the original affidavit is attached, Minn. Stat. § 115B.17 does not contain a requirement for such a signature and affidavit. Heartland's agreement to provide the signature and affidavit is not intended to be an admission that MPCA has the authority to require it, or that Heartland is subject to any other statutory, regulatory or other requirement. Heartland waives no rights in responding to the information requested.

Very truly yours,

Grace Koh Angelos

Grace Koh Angelos

PIGSEYE.RES

STATE OF ILLINOIS)
) SS:
COUNTY OF COOK)

AFFIDAVIT OF LAWRENCE S. ADELSON

I, Lawrence S. Adelson, state that I am the Vice President and General Counsel of CMC Heartland Partners. I certify that CMC Heartland Partners has made a diligent search of its records and has conducted a diligent interviewing process in connection with the preparation of the attached Response.

Lawrence S. Adelson
Vice President and General Counsel
CMC Heartland Partners

SUBSCRIBED AND SWORN
to before me this 15th
day of November, 1990

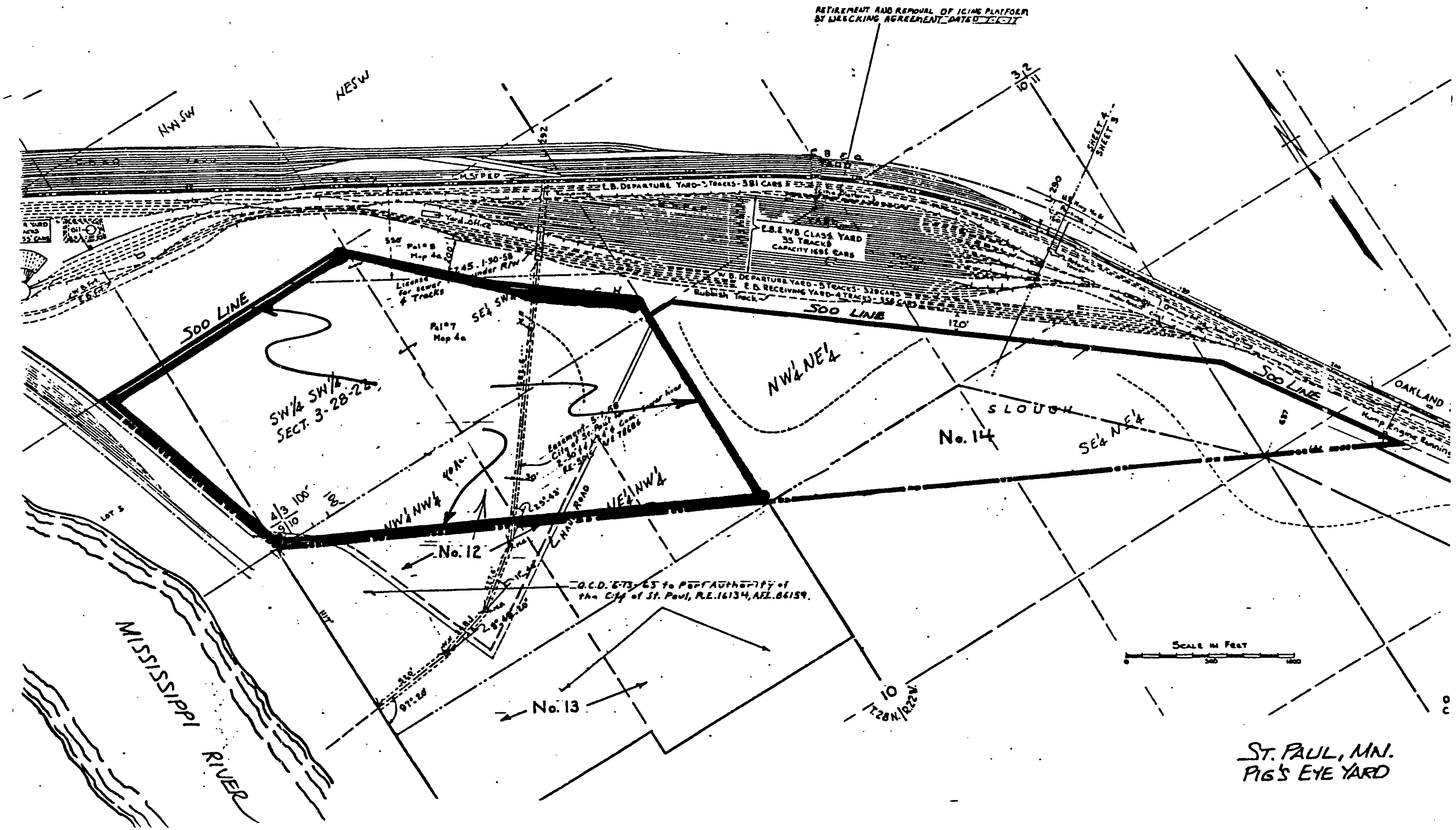
Stella C. Strock
Notary Public

" OFFICIAL SEAL "
STELLA C. STROCK
NOTARY PUBLIC, STATE OF ILLINOIS
MY COMMISSION EXPIRES 10/24/93

EXHIBIT A

MAP OF THE RAILROAD PARCEL
AND THE LEASED AREAS

EXHIBIT A



01362

EXHIBIT B

LEASES BETWEEN THE CITY OF
ST. PAUL AND THE CHICAGO, MILWAUKEE,
ST. PAUL & PACIFIC RAILROAD COMPANY

THIS AGREEMENT, Made this 1st day of May, A. D. 1957, by and between CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC RAILROAD COMPANY, a Wisconsin Corporation, hereinafter called "Railroad Company", and CITY OF SAINT PAUL, a Municipal Corporation of the State of Minnesota, hereinafter called "Licensee",

W I T N E S S E T H

WHEREAS, the Licensee desires the right, license and privilege to use for the purpose of detonating, firing, exploding or otherwise destroying and rendering harmless, ammunition, fire arms, bombs or other machines and devices containing explosive materials or substances, upon a parcel of land measuring 100 feet square, being a part of the Railroad Company's property in the NE¼ NW¼ of Section 10, Township 28 North, Range 22 West, in the City of Saint Paul, Minnesota, the location of said parcel of land being more particularly indicated by the broken yellow outline on the plat dated March 8, 1957 hereto attached and made a part hereof, which right, license and privilege the Railroad Company is willing to grant.

NOW, THEREFORE, in consideration of the sum of ONE AND NO/100 ($1.00) DOLLARS to be paid by the Licensee to the Railroad Company, the receipt whereof is hereby acknowledged, and in consideration of the covenants and stipulations hereinafter recited, the parties hereto hereby agree as follows:

1. The Railroad Company hereby grants unto the Licensee the right, license and privilege to use said parcel of land for the purposes hereinabove recited.

2. The Licensee hereby agrees as follows:

(a) That the rights herein granted to the Licensee shall be exercised and executed only by duly authorized officers of the Police Department of the Licensee.

(b) That live explosives or other hazardous materials, no matter how contained, shall not be stored or buried upon said premises, except for temporary periods when such explosives or hazardous materials are left under guard by members of the Licensee's Police Department.

(c) That the Licensee shall provide warning signs and other safeguards as may be necessary whenever said premises are used or about to be used for the purposes hereinabove recited.

TERMINATED
EFFECTIVE 8-19-58 ON 10-29-58
SUPERSEDED BY No. 66368

(d) That the Licensee shall, and hereby agrees that it will indemnify and save harmless the Railroad Company, its successors and assigns, from all liability, cost and expense for loss of or damage to property of whatsoever kind, and for injury to or the death of a person or persons by whomsoever sustained which may be caused by, result from, or be occasioned in any manner by the exercise of the right, license and privilege herein granted.

X 3. This agreement shall extend to and be binding upon the parties hereto and their respective successors and assigns; PROVIDED, however, that either party hereto may, without liability for damage therefor to the other party, terminate this agreement at any time by giving to the other party notice in writing of its desire so to do. Upon the effective date of any such termination the Licensee shall restore said premises to a condition satisfactory for general purposes.

IN WITNESS WHEREOF, the parties hereto have caused this agreement to be executed as of the day and year first above written.

CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC RAILROAD COMPANY

P. A. Smithmeyer
Witness

By J. J. Dooley
Industrial Commissioner

CITY OF SAINT PAUL.

Attest:
Joseph R. Okoneski
City Clerk

By Joseph E. Dillon
Mayor

Countersigned:
Joseph J. Mitchell
Comptroller

By Robert F. Peterson
Commissioner of Public Safety

Approved as to form and execution
this 24th day of MAY 1957
T. L. O'Toole
Assistant Corporation Counsel.

FORM APPROVED
J. Goggin
General Attorney C. M. St. P. & P. R.R. Co.

Form approved
T. L. O'Toole
Assistant Corporation Counsel

L I C E N S E 66368 01366

THIS AGREEMENT, Made this 19th day of AUGUST, 1958, by and between CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC RAILROAD COMPANY, a Wisconsin Corporation, hereinafter called "Railroad Company", and CITY OF SAINT PAUL, a Municipal Corporation of the State of Minnesota, hereinafter called "Licensee",

W I T N E S S E T H

WHEREAS, the Licensee desires the right, license and privilege to use for the purpose of detonating, firing, exploding or otherwise destroying and rendering harmless, ammunition, fire arms, bombs or other machines and devices containing explosive materials or substances, upon a parcel of land measuring 100 feet square, being a part of the Railroad Company's property along the south line and in the southwesterly part of the SW¼ SW¼, Section 3, Township 28 North, Range 22 West, in the City of St. Paul, Minnesota, the location of said parcel of land being more particularly indicated by the red outline on the plat hereto attached and made a part hereof, which right, license and privilege the Railroad Company is willing to grant.

NOW, THEREFORE, in consideration of the sum of ONE AND NO/100 ($1.00) DOLLARS to be paid by the Licensee to the Railroad Company, the receipt whereof is hereby acknowledged, and in consideration of the covenants and stipulations hereinafter recited, the parties hereto hereby agree as follows:

1. The Railroad Company hereby grants unto the Licensee the right, license and privilege to use said parcel of land for the purpose hereinabove recited.

2. The Licensee hereby agrees as follows:

(a) That the rights herein granted to the Licensee shall be exercised and executed only by duly authorized officers of the Police Department of the Licensee.

(b) That live explosives or other hazardous materials, no matter how contained, shall not be stored or buried upon said premises, except for temporary periods when such explosives or hazardous materials are left under guard by members of the Licensee's Police Department.

(c) That the Licensee shall provide warning signs and other safeguards as may be necessary whenever said premises are used or about to be used for the purposes hereinabove recited.

(d) That the Licensee shall, and hereby agrees that it will indemnify and save harmless the Railroad Company, its successors and assigns, from all liability, cost and expense for loss of or damage to property of whatsoever kind, and for injury to or the death of a person or persons by whomsoever sustained which may be caused by, result from, or be occasioned in any manner by the exercise of the right, license and privilege herein granted.

3. This agreement shall supersede and replace that certain agreement dated May 1, 1957 between the parties hereto in which the Railroad Company granted to the Licensee the right, license and privilege to use a parcel of land in the NE¼ NW¼ of Section 10, Township and Range aforesaid.

4. This agreement shall extend to and be binding upon the parties hereto and their respective successors and assigns; PROVIDED, however, that either party hereto may, without liability for damage therefor to the other party, terminate this agreement at any time by giving to the other party notice in writing of its desire so to do. Upon the effective date of any such termination the Licensee shall restore said premises to a condition satisfactory for general purposes.

IN WITNESS WHEREOF, the parties hereto have caused this agreement to be executed as of the day and year first above written.

CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC RAILROAD COMPANY

P. R. Smithmeyer
Witness

By J. Cooley
Director - Industrial and Real Estate Development

CITY OF SAINT PAUL

Attest:

Joseph R. Okoneski
City Clerk

By Joseph E. Dillon
Mayor

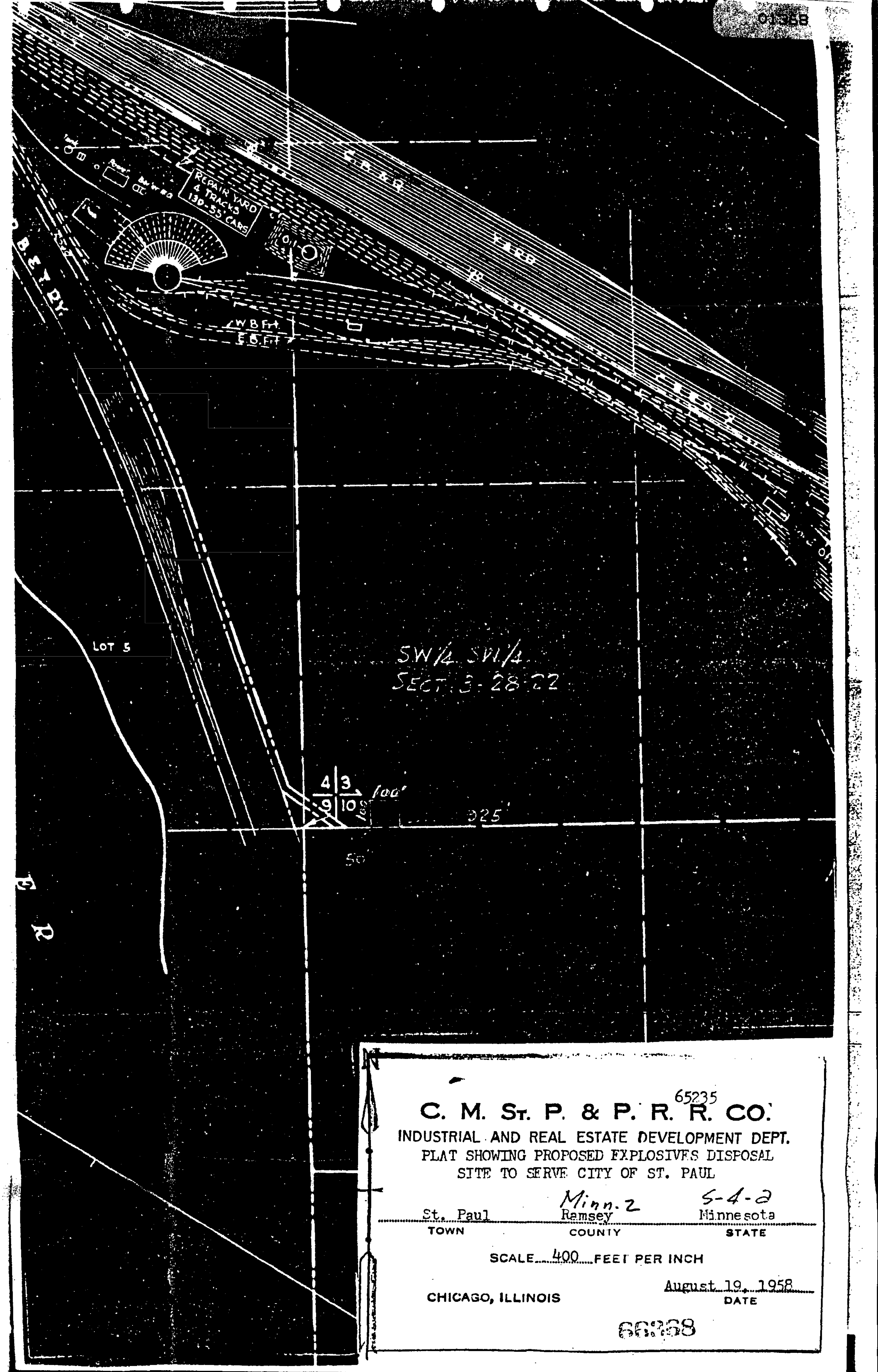
Countersigned:

Joe Mitchell
Comptroller

By Robert F. Peterson
Commissioner of Public Safety

Approved as to form and execution
this 23 day of October 1958
Robert E. O'Connell
Corporation Counsel

66268



65235

C. M. St. P. & P. R. R. CO.

INDUSTRIAL AND REAL ESTATE DEVELOPMENT DEPT.

PLAT SHOWING PROPOSED EXPLOSIVES DISPOSAL
SITE TO SERVE CITY OF ST. PAUL

Minn. 2 5-4-2

TOWN	COUNTY	STATE
St. Paul	Ramsey	Minnesota

SCALE 400 FEET PER INCH

CHICAGO, ILLINOIS

DATE: August 19, 1958

66268

01369

69895

REV. 67772
T.C.T.Div.

THIS AGREEMENT, Made this 6th day of [illegible], A. D. 1962, by and between CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC RAILROAD COMPANY, a Wisconsin corporation, hereinafter called "Railroad Company" and CITY OF SAINT PAUL, a municipal corporation of the State of Minnesota, hereinafter called "City",

WITNESSETH:

That the Railroad Company, in consideration of the sum of ONE AND NO/100 ($1.00) DOLLAR to it paid by the City, the receipt whereof is hereby acknowledged, and in further consideration of the faithful performance by the City of all the agreements herein contained, hereby grants unto said City the right, license and privilege of using for an all purpose dump the portion of said Railroad Company's property at Saint Paul, Minnesota, shown outlined in yellow on the blue print dated August 6, 1962 hereto attached and made a part hereof; the dumping operations to be of the so-called Sanitary Fill Method with the dump filled in layers of not more than 6 or 7 feet deep and covered at the end of each day with earth, rubble or other waste materials from paving and wrecking jobs.

SUBJECT ALWAYS to the observance and performance by the City of all and singular the following conditions to be by it observed, kept and performed, as follows, to-wit:

1. That the City will fill said dump to an elevation to be determined by the Railroad Company and that it will supervise said dump at all times when the same is in use, and separate all combustible material for burning at certain times on the filled portion of the dump.

2. That the City will install and maintain a water line for fire protection and provide an outlet for any drainage lines which may empty into the dump.

3. That the City will perform all of its work under this agreement at its sole cost and expense and to the satisfaction of the Chief Engineer of said Railroad Company or his authorized representative.

4. That the City will indemnify and save harmless the Railroad Company, its successors and assigns, from all liability, cost [illegible]

FILE COPY
DO NOT DETACH

PARED BY
NEH
ECKED BY
A

loss of or damage to property and injury to or death of persons, by whomsoever sustained, which may be caused or occasioned in any manner by reason of the work to be performed on said Railroad Company's right of way.

5. The parties hereto, by the execution of this license, hereby terminate any prior licenses of the premises herein demised.

6. This agreement shall extend to and be binding upon the parties hereto and their respective successors and assigns; PROVIDED, however, that the Railroad Company may, without liability for damage therefor, terminate this agreement at any time by giving to the City six (6) months notice in writing and that upon the effective date of such termination, the filling material placed upon said Railroad Company's premises shall become the property of the Railroad Company.

IN WITNESS WHEREOF, the parties hereto have caused this agreement to be executed as of the day and year first above written.

CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC
RAILROAD COMPANY

______________________ By______________________
Witness Director - Real Estate and
Industrial Development

CITY OF SAINT PAUL

Attest:

______________________ By______________________
City Clerk Mayor

Countersigned:

______________________ By______________________
Comptroller Commissioner of Public Works

01371

69895

AMENDMENT TO AGREEMENT

THIS AGREEMENT, dated this 25th day of Sept, 1969, by and between the Chicago, Milwaukee, St. Paul and Pacific Railroad Company, a Wisconsin corporation, hereinafter referred to as "Railroad Company", and the City of Saint Paul, a municipal corporation under the laws of the State of Minnesota, hereinafter referred to as "City";

WITNESSETH:

WHEREAS, Railroad Company and City have entered into an agreement dated November 6, 1962, whereby the City was granted the right to use land owned by Railroad Company for landfill purposes, subject to certain conditions contained there, and it is now mutually agreed that the said agreement should be amended so as to provide for an annual rental therefor;

NOW, THEREFORE, The parties do hereby agree that that certain agreement referred to above shall be amended to add the following provision:

> "In consideration for the right to use the real property of the Railroad Company for all purpose dump, the City agrees to pay an annual rental, the amount thereof to be equal to the amount of annual real estate tax levied against the real property which is the subject of the agreement herein. It is agreed that the annual rental shall be paid by the City within thirty (30) days from the date of receipt of a copy of the annual tax

TERMINATED
EFFECTIVE 1-1-78 ON 11-24-78
By Agreement

MN-2
S-61

statement together with a request
for payment therefor from the Rail-
road Company."

It is further agreed by and between the parties hereto that this amendatory agreement shall take effect immediately and that the first annual rental shall be paid by the City during the year of 1969, and continue to be paid thereafter until the agreement shall be further amended or terminated in the manner therein provided.

It is further mutually agreed by and between the parties hereto that all the terms and conditions of that certain agreement referred to above shall continue in full force and effect, except as modified by this amendatory agreement.

IN WITNESS WHEREOF, the parties hereto have caused this agreement to be executed as of the day and year first above written.

In Presence Of:
E. G. Tyckoson Jr.

CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC RAILROAD COMPANY

By
VICE PRESIDENT-REAL ESTATE AND INDUSTRIAL DEVELOPMENT

CITY OF SAINT PAUL

By Thomas R. Byrne
Mayor

Commissioner of Public Works

Harry E. Marshall
City Clerk

Countersigned:

City Comptroller

Approved as to Form:

Assistant Corporation Counsel

Approved as to form and execution this 3 day of Sept, 1969.

Assistant Corporation Counsel

RAILROAD COPY **This Indenture** MINN. 01373

Made this 1st day of MARCH, A. D. 1978, by and between the STANLEY E. G. HILLMAN, as Trustee, of the property of, CHICAGO, MILWAUKEE, ST. PAUL and PACIFIC RAILROAD COMPANY Debtor hereinafter referred to as "Railroad Company," and

CITY OF ST. PAUL

of P. O. address 234 City Hall, St. Paul, Minnesota 55102 hereinafter referred to in the singular neuter gender as "Lessee."

W I T N E S S E T H :

FIRST: The Railroad Company does hereby lease, demise and let unto the Lessee, the following piece(s) or parcel(s) of land lying within and being a portion of its property at the Station of ST. PAUL, County RAMSEY, State of MINNESOTA, and described as follows, to wit;

AN IRREGULAR-SHAPED parcel of land containing 117.6 acres, more or less, and being part of the Railroad Company's Pig's Eye Yard property in the City of St. Paul, in the County and State aforesaid, said parcel located in Sections 3, 4 and 10, Township 28 North, Range 22 West and lying southwesterly of the Railroad Company's hump yard, the location thereof being more particularly indicated in red on the plat attached hereto and made a part hereof.

Term Effective Date

TO HOLD for the term of FIVE (5) year(s) from the first day of JANUARY, A. D. 1978, subject, however, to the right of either party to terminate this Indenture by giving to the other sixty (60) days written notice of its desire so to do and to the following express conditions, viz:

Rental

1. That the Lessee shall pay as rent for said demised premises the sum of SIX THOUSAND AND NO/100 ($6,000.00) Dollars per, annum, payable annually in advance.

Taxes

2a. That the Lessee shall pay all taxes and assessments (Except special assessments for permanent improvements) legally levied or assessed against said premises during the term hereof or any extension thereof; and in case of special assessments for permanent improvements, the annual rental will be increased by ten percent (10%) of such assessment; except that the amount of taxes payable for the year in which the lease is terminated shall not exceed the portion thereof accrued from the first day of the year to the effective date of termination.

2b. That the Lessee shall pay all taxes and assessments legally levied or assessed against its improvements located upon the demised premises during the term hereof or any extension thereof, and in the event said lease is terminated, Lessee shall pay the full amount assessed against said improvements for the year in which termination occurs.

Purpose

3. That the Lessee shall use said premises as a site for STORAGE OF DISEASED TREES and for no other purpose whatsoever, unless the Railroad Company shall consent in writing to a change of use, and that it will not, without like consent, assign this lease or under-lease said premises or any part thereof.

TERMINATED

EFFECTIVE

Land Lease No. 82316

4. That the Lessee shall continuously carry on its business upon said premises in an efficient manner, unless discontinued by written consent of the Railroad Company; that said premises shall be used and the business thereon conducted, insofar as it may affect the interests and operations of the Railroad Company, to the approval of its General Manager; and that it will not in any way obstruct or interfere with the tracks of the Railroad Company.

5. That the property herein demised is leased in its condition at the date hereof; that any and all facilities, including overhead and underground fixtures, located thereon shall be maintained and operated as heretofore.

6. That the Lessee shall erect upon said premises the facilities appropriate for the uses herein mentioned, and have the same completed and ready for use within three months from the date of this lease; and that all doors on the track side of any building or buildings shall be so constructed as to open inward or be of a sliding type.

7. The Lessee agrees to keep said premises and all improvements thereon in a neat and orderly condition, and to cover all improvements with one or more coats of approved paint, whenever required so to do by the Railroad Company, and that no signs nor advertisements of any description shall be permitted to be painted or posted upon said improvements, or about said premises, other than those of the business of the Lessee, and as shall be approved by the Railroad Company.

8. It is understood that the movement of railroad locomotives includes some risk of fire, and the Lessee assumes all liability for and agrees to indemnify the Railroad Company against loss or damage to property of the Lessee or to property upon the Lessee's premises, arising from fire caused by locomotives operated by the Railroad Company in the vicinity of said demised premises, except to the premises of the Railroad Company, and to rolling stock belonging to the Railroad Company or to others, and to shipments in the course of transportation.

9. That the Lessee hereby releases the Railroad Company from and agrees to indemnify it against all loss, damage or injury, caused by or resulting from any act or omission of the Lessee, its employees or agents, to the person or property of the parties hereto and their employees, and to the person or property of any other person or corporation, while on or about said premises, and if any claim or liability other than from fire shall arise from the joint or concurring negligence of both parties hereto, it shall be borne by them equally.

10. That in any case where the covenants, agreements and releases contained in the two preceding paragraphs shall be held not to be valid in law, the Railroad Company shall have the full benefit of any insurance affected by the Lessee upon the persons or property injured or destroyed.

11. That the Lessee shall comply with all applicable Federal and State laws and regulations and municipal ordinances in respect of the conduct of its business upon said premises; and shall comply with all applicable ordinances, rules, regulations, requirements and laws of any governmental authority controlling environmental standards and conditions on the demised premises. If, as a result of Lessee's operations hereunder, any such ordinance, rule, regulation, requirement or law is violated, Lessee shall protect, save harmless, defend and indemnify Railroad Company from and against any penalties, fines, costs and expense, including legal fees and court costs imposed upon or incurred by the Railroad Company, caused by, resulting from or connected with such violation or violations.

12. That any violation of or failure to comply with any condition herein, within thirty (30) days written notice of violation, shall terminate this lease without any further notice or act upon the part of the Railroad Company, and thereupon it may re-enter and take possession of said premises, as by law provided.

13. Nothing herein contained shall affect the right of either party to terminate this lease on written notice as herein provided, and in the event of such termination any unearned rental shall be refunded.

14. The parties hereto, by the execution of this lease, hereby terminate any prior leases of the premises herein demised.

15. Lessee shall, upon any termination of this lease, restore the demised premises to its condition prior to the storage of the diseased trees thereon and to seed it all to the satisfaction of the Railroad Company and XXXXXX XXXXXXXXXXXXXX the Minnesota Pollution Control Agency.

This agreement is binding on Stanley E. G. Hillman, not as an individual, but solely in his capacity as Trustee.

SECOND: The Lessee hereby accepts the foregoing lease, and covenants and agrees faithfully to observe and perform all the terms, conditions and requirements therein contained, and it further agrees that it will surrender said demised premises at any termination of this lease, and will, on or before the effective date of such termination, completely remove from said premises all property owned or placed thereon by it, and will restore the premises to a state of usefulness for general purposes; that failure so to remove all such property shall be conclusively deemed abandonment thereof to the Railroad Company, thereby waiving all its right, title and interest in and to such abandoned property; and that in such case the Railroad Company shall, from and after the effective date of any termination, be at full liberty to re-enter and take possession of all the demised premises and, at the sole expense of Lessee, to remove therefrom all such property there remaining and to restore said premises to a state of usefulness for general purposes, and the Lessee hereby binds itself to pay unto the Railroad Company promptly upon receipt of bill therefor, the entire cost and expense of such removal and restoration; or, at Railroad Company's own sole option, to appropriate and dispose of any such property without any liability or accountability therefor; but nothing herein contained shall preclude the Railroad Company from any other legal remedy.

No receipt of money by the Railroad Company from Lessee prior to or after the expiration date or termination of this lease or after the service of any notice, or after commencement of any suit, or after final judgment for possession of the premises shall reinstate, continue or extend the term of this lease or affect any such notice demand or suit.

That the right or interest created by this instrument shall be subject and subordinate to the continuing lien of the First Mortgage dated as of January 1, 1944, executed and delivered by Chicago, Milwaukee, St. Paul and Pacific Railroad Company to Continental Illinois National Bank and Trust Company of Chicago, Trustee, and all mortgages supplementary thereto, and to the lien of the General Mortgage dated as of January 1, 1944, executed and delivered by Chicago, Milwaukee, St. Paul and Pacific Railroad Company to Harris Trust and Savings Bank, Trustee, and all mortgages supplementary thereto.

All the terms, conditions and covenants of this lease shall during its continuance, be binding upon the Railroad Company, its successors and assigns, and upon the Lessee, its successors and assigns, and upon the Lessee, its successors and assigns, heirs and legal representatives.

IN WITNESS WHEREOF, the parties hereto have caused these presents to be duly executed as of the day and year first above written.

STANLEY E. G. HILLMAN, as Trustee, of the property of,
CHICAGO, MILWAUKEE, ST. PAUL and PACIFIC RAILROAD COMPANY
Debtor

G. G. Grudnowski
~~Witness for the Railroad Company~~
Asst. Secretary
G. G. GRUDNOWSKI

By W. L. Smith
~~Vice President~~ W. L. SMITH
PRESIDENT

CITY OF ST. PAUL

Rose Mix
Clerk

By George Latimer
Mayor

Approved as to Form:

Jerome J. Segal
Assistant City Attorney

By Bernard Carlson
Director, Department of Finance & Management Services
JWD

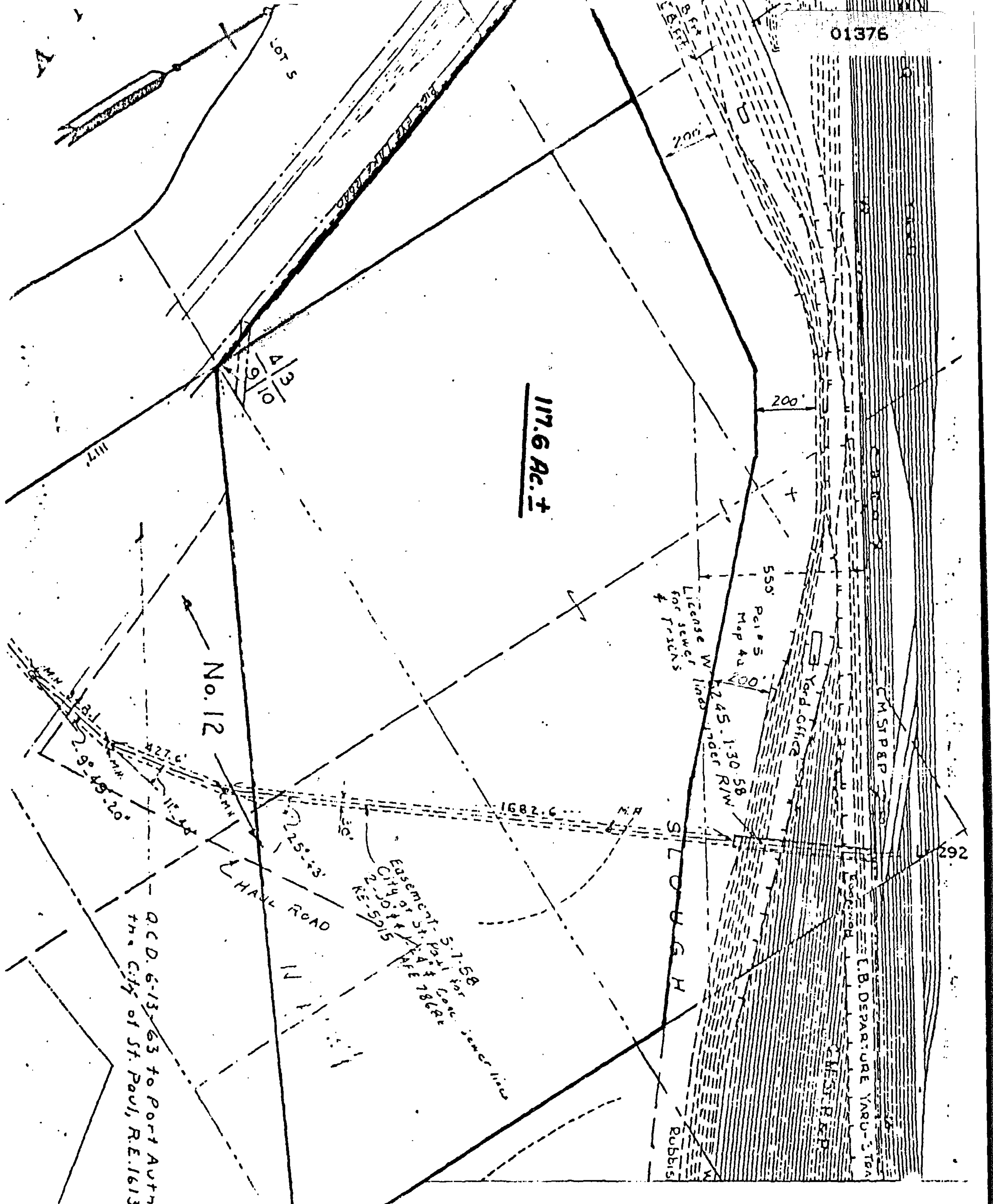
Funding: 33123

APPROVED
B. H. Bobbitt
Asst. Vice President

FORM APPROVED
C. M. Conway

Lease No. 82316

01376



C. M. St. P & P. R. R. CO.

REAL ESTATE, ECONOMIC AND RESOURCE DEVELOPMENT DEPT

PLAT SHOWING PROPERTY TO BE LEASED TO

CITY OF ST. PAUL

For: storage of diseased trees

Minn.-Dak. Div.	Minn. 2	Map 4
ST. PAUL	RAMSEY	MINNESOTA
TOWN	COUNTY	STATE

SCALE 400 FEET PER INCH

3, 4 & 10	28 North	22 West	March 1, 1978
Section	Township	Range	DATE
			CHICAGO, ILLINOIS

EXHIBIT C

PIG'S EYE DUMP
CUSTOMER LISTING

01378

EXHIBIT C
CUSTOMER LISTING

NAME & ADDRESS	DATES	VOLUME ($YD.^3$)[1]	WASTE CHARACTERIZATION	CURRENT CONTACT	DISPOSAL AREA[2]
1. City of St. Paul Department of Public Works	1957 - Present	Total volume unknown	Unknown	Unknown	Unknown
234 City Hall & Court House	1969	1,390,847	Unknown		
	1970	1,557,949	Unknown		
St. Paul, MN 55102	1-10/71	1,463,654	Unknown		
2. Metropolitan Waste Control Commission (MWCC) 350 Metro Square	1973	Unknown	"Refuse" from the Metropolitan Waste Water Treatment Plant (MWWTP).	Unknown	Unknown
Building	11/74	26,500	Ash material.		Unknown
St. Paul, MN 55101		7,500	Topsoil.		Unknown
		3,800	Topsoil mixed with silt and sand.		Unknown
		33,000	Ash mixed with silt.		Unknown
	1975	200,000	Fill material from excavation work at the MWWTP		
	12/77 - 1/78	136,000	Sludge incinerator ash.		See Fig. 1
	1978	Unknown	Grit and Screening		15' west of ash ponds[3]
	1979	Unknown	Concrete, scrap wood,		Unknown

1/ Volume is in cubic yards unless otherwise noted.

2/ "Disposal Area" denotes specific areas within the Pig's Eye Dump.

3/ It is unclear whether this is within Pig's Eye Landfill proper.

01379

	NAME & ADDRESS	DATES	VOLUME (YD.^{3})	WASTE CHARACTERIZATION	CURRENT CONTACT	DISPOSAL AREA
				scrap metal, metal drum, household garbage and paper, and demolition debris.		
		1980	100,000	Ash from incineration of wastewater sludge.		See Fig. 2
3.	Shafer Construction Co.[4/] Forest Lake, MN	1978	Unknown	Fill for a haul road.	Unknown	"Wetland"[5/]
4.	St. Paul Water Dept. 277 N. Hamline Ave. St. Paul, MN 55104	1978	Unknown	Excavated material from the Pig's Eye Dump.	Unknown	"Wetland"[6/]
5.	Whirlpool Corporation Payne Avenue (___) 776-8511.	Unknown	Unknown	Unknown	Unknown	Unknown
6.	Selby District Commercial _____	5/20/69	274	Unknown	Unknown	Unknown

[4/] Shafer was working under a contract with MWCC.

[5/] The document with the information relating to this disposer states that the fill was placed in the "wetland" area. We assume that this is referring to the Haul Road at the Pig's Eye Dump.

[6/] The document which relates to this information states that this material was placed in the wetland area east of tree chipping facility at the Pig's Eye Dump. The exact location is uncertain.

01380

NAME & ADDRESS	DATES	VOLUME (YD.^{3})	WASTE CHARACTERIZATION	CURRENT CONTACT	DISPOSAL AREA
7. Ramsey County Recreation Dept.	5/69	48	Unknown	Unknown	Unknown
8. Phallen Area Commercial Council	5/69	98	Unknown	Unknown	Unknown
9. East Side Community	5/17,18,22/71	275	Unknown	Unknown	Unknown
10. Madel Neighborhood Beautification	5/17,18,22/71	329	Unknown	Unknown	Unknown
11. Dayton's Bluff Community Center	5/17,18,22/71	68	Unknown	Unknown	Unknown
12. Minnesota Mining & Manufacturing (___) PR6-8811, Ext. 6134	Unknown	20-25 loads/wk	Unknown	Unknown	Unknown
13. Haul-A-Way System	10/61 - Unknown	5/wk	Unknown	Unknown	Unknown
14. McKnight Bros. South St. Paul, MN	Unknown	4/wk	Unknown	Unknown	Unknown
15. Chicago, Milwaukee St. Paul & Pacific Railroad	1969-1972	370/wk[7]	General garbage, dunnage, steel strapping and food from refrigerated cars.	Company does not exist.	Unknown

[7] This information was obtained from a hand-written memorandum found in the City of St. Paul's files and reflects the average volume for the period between May 26, 1969 and July 20, 1969. The memorandum references Roy Johnson as the City's contact at the Railroad. Roy Johnson, a former Railroad employee, has advised Heartland that the weekly volume varied.

NOTE: Because this information has been gathered from old documents, some of which are handwritten and not entirely legible, Heartland has responded to the extent reasonably possible. A copy of this documentation is attached and is identified by number to correspond to each of the listed customers.

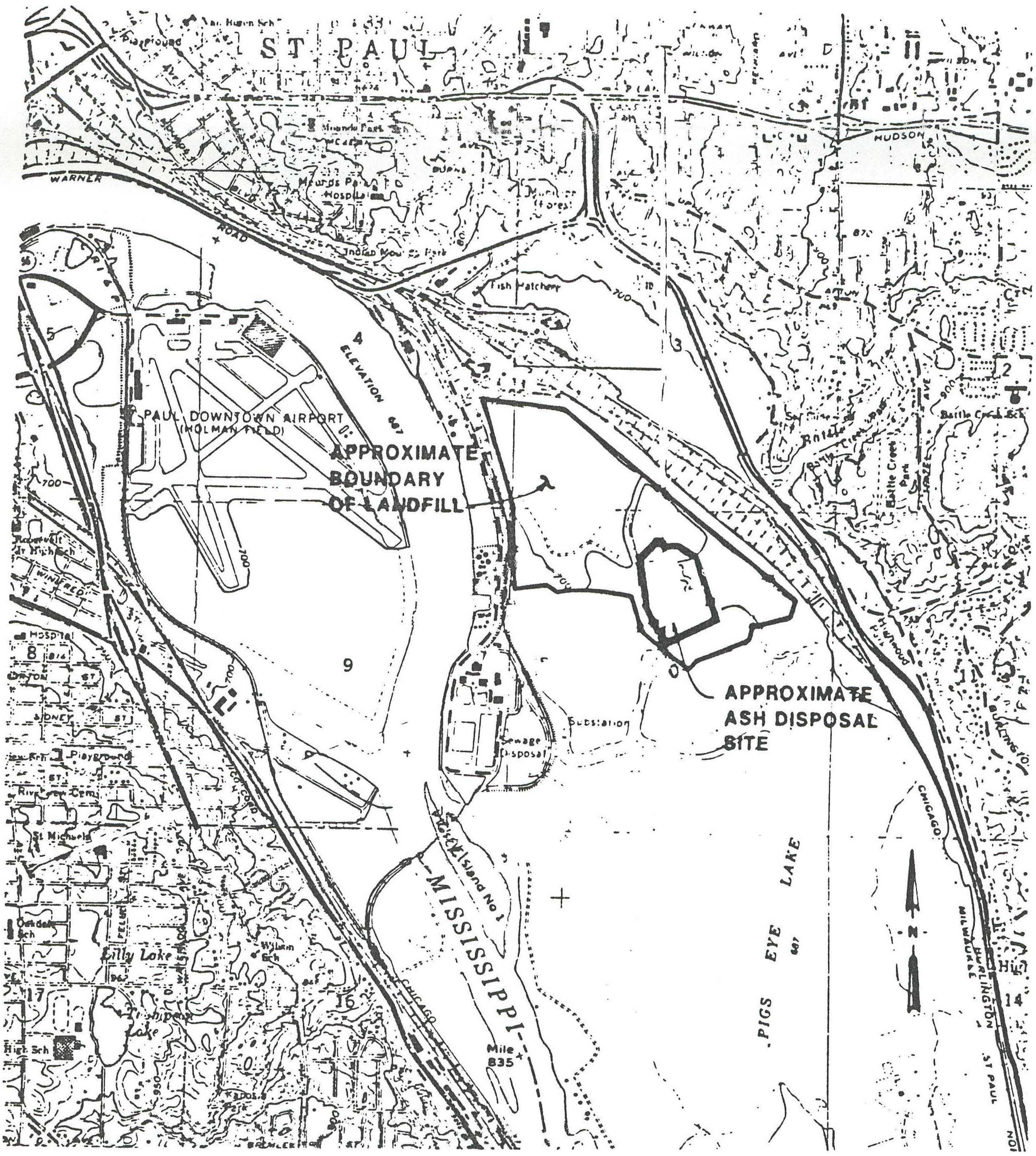


FIGURE 1

0 2000'

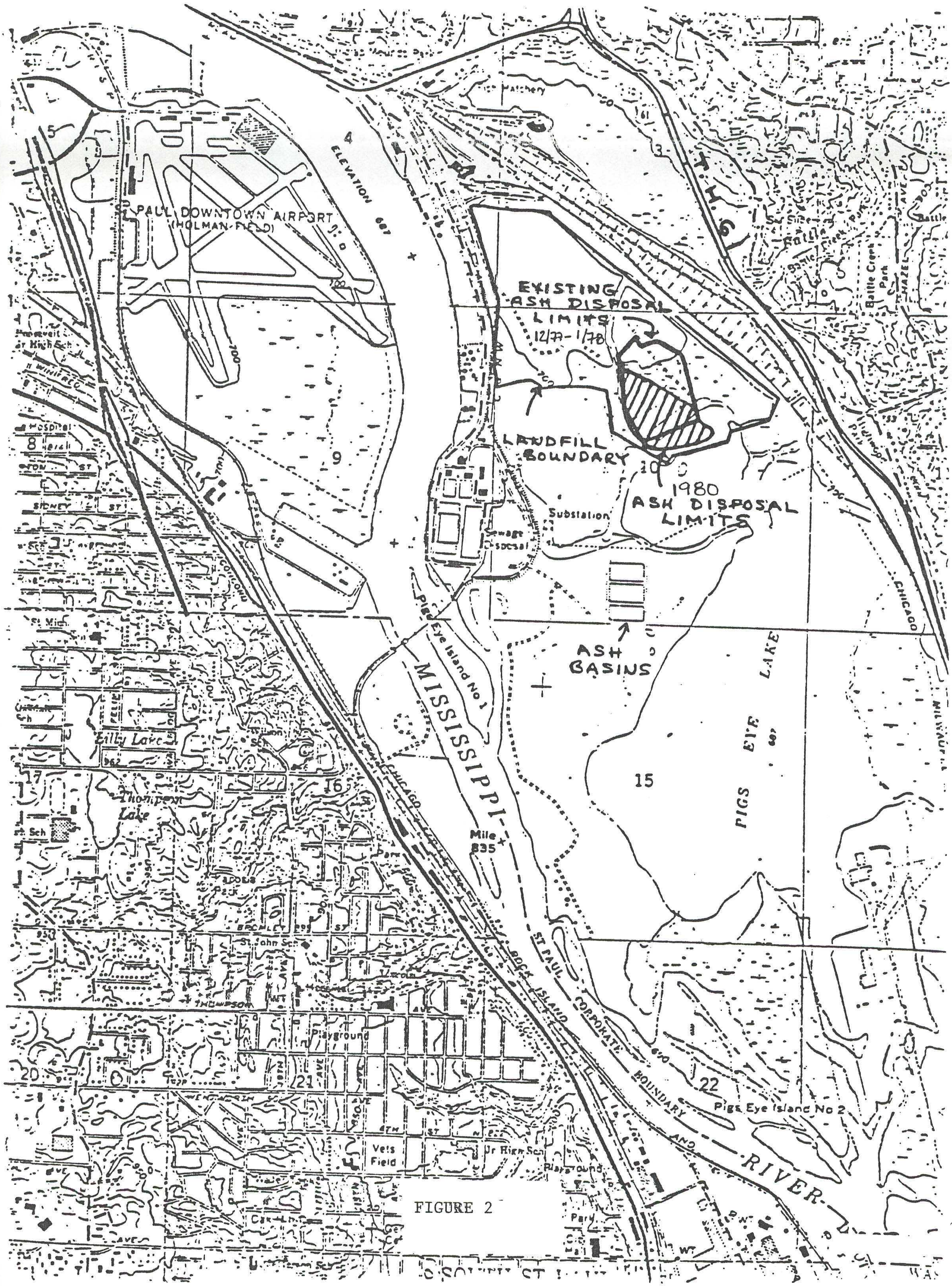


FIGURE 2

01383

DOCUMENTS RELATING TO:

THE CITY OF ST. PAUL (EXHIBIT C.1)

THE DEPARTMENT OF PUBLIC WORKS
OF THE
CITY OF ST. PAUL
INTER-OFFICE COMMUNICATION

TO: MEMBERS OF SOLID WASTE TRANSFER STATION SITE SELECTION COMMITTEE:

Mrs. George Latimer, Chairman
Mr. William Gillespie
Mr. Burnell Beerman
Mrs. Sharon Powell
Mr. Daryl Thayer
Mr. Gary Norstrem

ADVISORY MEMBERS:

Mr. Richard Schnarr
Mr. Patrick Bradley
Mr. Eugene Macauley - 451 City Hall

FROM: DONALD E. NYGAARD, ASST. ENGINEER OF MAINTENANCE SERVICES DEN

DATE: NOVEMBER 18, 1971

SUBJECT: IDEAS ON SOLID WASTE TRANSFER STATIONS FOR THE CITY OF ST. PAUL

At your November 11th meeting I was asked to draw up a preliminary report to serve as a guideline for the committee on the subject of transfer operations in St. Paul. It was requested that we include some technical data on the tonnages of waste that are received at Pig's Eye and, of course, the tonnages that should be provided for in transfer stations. Several of us in the Maintenance Services Department of Public Works have been giving thought to transfer stations over the past four or five years. They first were considered in conjunction with our present Pig's Eye Disposal site and now, of course, in terms of transfer stations with the ultimate disposal site being a considerable distance from the City and, very likely, some place in Washington County. In my judgment there are three key areas to be considered in the subject of transfer stations. First it must be explained to our citizens why there is a need for transfer stations and what they will accomplish; second, what are the standards and criteria for a good transfer type operation; third, how many transfer stations would be needed in St. Paul and where should they be located; and finally, how shall the transfer stations be financed and operated. I will discuss each of these points. It is hoped that some of these thoughts will be helpful to the committee.

I. DEFINITION OF THE PROBLEM - WHY ARE TRANSFER STATIONS NEEDED IN ST. PAUL?

A. For many years the City of St. Paul had two landfill facilities, Fish Hatchery and Pig's Eye. Fish Hatchery, a 38-acre site was located immediately south of Warner Road just westerly of the intersection with Trunk Highway #61. It was used primarily by private citizens bringing their own refuse down to the disposal site. Fish Hatchery was completed this past spring and completely covered over with earthen material, landscaped, etc., and fenced off. It has been standing vacant since then.

Pig's Eye Landfill which is located south of Fish Hatchery and immediately adjacent to the Sanitary Waste Water Treatment Plant was and is the major landfill facility in St. Paul. It comprises approximately 320 acres and will generally take two 7-foot lifts over the entire area. At the present time we have one 7-foot lift over the whole site and are working on the second one. All refuse hauling, including private and City and all commercial for the City of St. Paul, as well as most of the surrounding suburbs, is being hauled into Pig's Eye. The Minnesota Pollution Control Agency has put the City of St. Paul on notice that Pig's Eye Landfill site must be shut down no later than July 1, 1972. The reason for this being that it is within the flood plain of the Mississippi River and is contrary to State Laws.

B. Since Pig's Eye is the only disposal facility in St. Paul, it takes an enormous quantity of refuse. In 1969, 1,390,847 cubic yards were disposed of at Pig's Eye, or 345,712 tons. In 1970, the quantity of refuse disposed rose to 1,557,949 cubic yards, or 389,488 tons. So far in 1971 we have the following figures by month:

January	111,385 cu. yds.	-	27,846 tons
February	107,719 " "	-	26,929 "
March	140,653 " "	-	35,163 "
April	174,500 " "	-	43,625 "
May	155,508 " "	-	38,877 "
June	169,060 " "	-	42,265 "
July	161,653 " "	-	40,413 "
August	156,236 " "	-	39,059 "
September	145,970 " "	-	36,492 "
October	140,770 " "	-	35,192 "

The average daily quantity of refuse disposed at Pig's Eye is 5,500 cubic yards, or 1,375 tons per day. This figure is based on the unit weight of one cubic yard of combined refuse including garbage and rubbish, of 500 pounds per cubic yard. Federal guidelines indicate that at the present time one person generates about 5.3 pounds of refuse per day. If we run this out on the basis of St. Paul's population, slightly in excess of 300,000, this works out to be about 750 tons of refuse generated per day. It is estimated that by 1980 the figure of 5.3 will have grown to 10 pounds per person per day, or about 1,500 tons per day in St. Paul. You will note that the 5.3 figure per person per day, or 750 tons per day, is somewhat less than the 1,375 tons disposed at Pig's Eye. Obviously, this comes about because most of the surrounding suburbs, including

West St. Paul, South St. Paul, Roseville, and Maplewood, and other suburbs are hauling large quantities of their refuse into Pig's Eye. In my judgment we should be designing transfer facilities for St. Paul to accommodate 2,000 tons per day based on a 10-hour work day. This would provide capacity for a projected refuse quantities through 1980.

C. Since the Pig's Eye Landfill site will be closed down by the State on July 1, 1972, a little more than six months away, and since Pig's Eye is presently handling approximately 1,375 tons of refuse per day, an enormous quantity, and since it is very unlikely that another landfill facility will be found close to St. Paul and, more than likely, it will be a joint facility with Washington County located some place east of St. Paul, it's very important that intermediate transfer stations be constructed whereby the smaller collection trucks can dump refuse at these points and the refuse would then be hauled in large 75 to 100-cubic yard semi trucks out to the final disposal site.

D. What present transfer stations and facilities are available in St. Paul? American Hoist and Derrick has shown the way to this point. American Solid Waste Systems, a subsidiary of American Hoist, recently constructed a small transfer station on Rosen Road easterly of the Midway Stadium. It's a small station of approximately 250 tons per day capacity. American Systems also constructed a solid waste baler in the Riverview Industrial Area of St. Paul in conjunction with the transfer station. The baler compresses the solid waste into a block approximately 3'x3'x4½' weighing 2,500 pounds. The bales are then ahuled to a landfill site in Inver Grove.

American Systems estimate that their baler will handle up to 1,000 tons per day operating two shifts with ultimate disposal costs being about $1.80 per ton. This figure covers the baling operation and disposal. American Systems are operating the baler with a 3-man crew. In the event Pig's Eye is closed down on July 1, 1972, the City of St. Paul would have available within the corporate limits the baler that would handle 1,000 tons and the Midway Stadium transfer station which could handle 250 tons, or a total capacity of 1,250 tons per day. ~~All three of these facilities would then total 1,500 tons of refuse per day~~. So, on paper at least, there would appear to be enough capacity to handle the generation. In our judgment from a practical standpoint, we can foresee enormous problems in attempting to handle the peak disposal at these ~~three~~ TWO sites. It would appear that traffic problems would be enormous and that we would have literally "mountains of refuse piled up". However, as a stop-gap measure until additional transfer stations could be constructed, it's possible that these ~~three~~ TWO facilities could handle the load.

II. WHAT ARE THE CRITERIA AND STANDARDS OF A GOOD TRANSFER STATION OPERATION?

A. As a rule they should be located in an industrially or light industrially zoned area. Or, in any case, they should be located on property that is buffered from residential areas and commercial areas as much as possible. Transfer stations that have been built within the Twin Cities and in other cities across the country have oftentimes been forced onto locations that are not entirely desirable, but public reaction is sometimes bitter to a transfer station similar to a landfill disposal site, although it has been proven that odors, noise, and other pollution factors are very minimal at a transfer station operation.

B. You must have good vehicle access to the site. This includes both the private vehicles and compactor refuse trucks coming in to dispose at the transfer station and, also, the huge 75-100 yard transfer trucks that haul the refuse out. Oftentimes it is desirable to locate a station at the intersection of possibly a freeway and a major arterial. The major arterial can bring the refuse compactor trucks and small vehicles in and go out the same route, whereas the transfer trucks would come off the freeway. The point is that the station must be located in an area that has good truck access.

C. Transfer stations are facilities that house a composite of various types of specialized equipment. The specialized equipment could include loaders, tractors, clamshells, stationary compaction equipment, large semi type tractors, etc. All of this specialized equipment is put together within a structure. The point being there is probably no one best "package unit" or brand name as such, rather it is a case of designing a structure and specifying the type of equipment to be installed within the structure that you feel best fits the need.

D. Transfer stations should be located as close as possible to the centroids of the collection operation. Obviously, to keep collection costs as low as possible, the transfer stations should be located stretegically to service the collection routes. The general trend across the country is to build larger transfer stations and fewer of them.

E. Transfer stations must be operated efficiently and kept "spotlessly" clean. All efficiently run stations are completely cleaned out at the end of the day and washed down with fire hoses. Most of the modern transfer stations built today are of the pit-type where the refuse trucks will back in against a railing and dump their load into a large pit. The transfer trucks themselves will then be loaded at a lower level from the pit. It has been proven that there are extremely high volume "surges" where for no explainable reason the volume of refuse coming in will be tremendously high. Therefore, it has been found practical to oversize the pits in order to hold the refuse so that it does not pile up on the floor and, also, that you don't have compactor trucks and other vehicles backed out into the streets.

F. More of a technical nature, of course, transfer stations must be spotted accurately on maps and length of haul to the disposal site should be computed, travel times also checked, also, a careful analysis should be made of all costs involved in the operation. The whole question of transfer stations, both where they should be located and the number of stations, is a question of economics and bears very close and careful cost studies and analysis.

III. HOW MANY TRANSFER STATIONS ARE NEEDED IN ST. PAUL AND WHERE SHOULD THEY BE LOCATED?

A. Transfer stations are, of course, rated by the capacity of refuse that they can handle per day. Usually it is based on a capacity for a 10-hour work day. Typical sizes would be a 250 tons per day, 500 tons per day, 750 tons per day, 1,000 tons per day, 1,500 tons per day, or even 2,000 tons per day and larger. At the present time we are generating approximately 1,375 tons of refuse per day at Pig's Eye so, to replace it, we are talking about possibly two transfer stations with a capacity of 750 tons per day, or possibly at the very most, three transfer stations of 500 tons per day capacity.

B. The rule of thumb often used in determining if you need transfer stations is if your haul is longer than 15 miles, it's usually feasible to construct a transfer station. Obviously with the future landfill to be located someplace east of St. Paul in Washington County, possibly, there is no question that the haul will far exceed the 15-mile rule of thumb. Then, we must ask, how many transfer stations are needed within St. Paul and where should they be located.

C. We must first bear in mind that all the refuse for the entire City of St. Paul as well as most of the surrounding suburbs, is presently being hauled to Pig's Eye itself. So, we could start off by considering one huge transfer station that would handle 1,500 tons per day. According to today's standards of transfer stations, this would not be an unduly large station. San Francisco recently constructed a 2,000 ton per day facility with a potential of expanding it to 5,000 tons per day. It was put in operation in October of 1970 and has been working out very well. It has space for 16 compactor trucks to dump into a pit about 65' wide and 220' long, with stalls at a lower level for two transfer trucks to be filled at the same time. Incidently, the San Francisco facility is operated with only 5 men. The idea of one large transfer facility for St. Paul should not be dismissed too quickly.

D. The next step would be to consider possibly two transfer stations located at strategic points around the City. They would be smaller stations of approximately 750 tons per day capacity. We may also consider three transfer stations, about 500 tons per day each, which would further aid the convenience of the collection operations. In our judgment it is not practical to consider transfer operations for a city the size of St. Paul smaller than 500 tons per day since the operating overhead for these facilities tends to get somewhat out of hand. So, we are talking about possibly three locations for transfer operations. Within the Maintenance Services Department of Public Works, we've looked at several locations around the City that may be considered for transfer facilities, and we'd like to suggest them to you:

1. Fish Hatchery Landfill site on Warner Road westerly of Trunk Highway #61. This is the site of the old landfill facility. The whole site comprises 38 acres, however, there is a large area approximately 15 acres as you come in the main entrance off Warner Road, that is owned by the Port Authority and would be an ideal location for a transfer facility since it could be buffered from Warner Road. The railroad tracks are located on the south and with Warner Road on the north, Trunk Highway #61 to the east, and then the Freeway I-94 just a little bit to the north, it makes an ideal location from a traffic standpoint. Also, it has been an established landfill site and has proven out as an effective location.

2. Midway Station Transfer Facility - This is the present site of the American Systems Transfer Station on Rosen Road easterly of Midway Stadium. The existing station is a very small facility rated at about 250 tons per day and probably is not well suited for a large scale municipal operation. It is an excellent location and possibly this facility could be enlarged or reconstructed to a transfer facility of at least 500 tons per day capacity or larger. It would serve the whole northwest quadrant of the City very well and there is excellent access to it.

3. Case and Mississippi site - This site is located just easterly of the frontage road along 35-E at the intersection of Case and Mississippi. Generally it is south of Maryland. This property was formerly the site of the Department of Public Works borrow pit. It has been filled in over the last year and landscaped and possibly would be a good site for a transfer facility. It has excellent access since the frontage road ties directly into 35-E and would serve the whole northeast quadrant of the City.

4. Southwest corner of Jackson and Arlington - This is privately owned property, however, we have considered it as a potential site for a transfer facility. 35-E is located less than one-half mile east of this location and we have both Jackson and Arlington which are major arterials. Also, the Soo Line Railroad tracks are adjacent to this property on the west which, if rail haul was ever considered, it would make this location suitable. Also, the tracks are up quite high which buffers the location from the west.

5. Pleasant and View Location - This is presently the site of the Maintenance Services Department yard facility. It is located between the railroad tracks on the north and the freeway which is not yet open, is immediately on the south. It would have good access to the Freeway. In our judgment it is a good location for the southwest portion of the City which would service the Highland Park area. It's very possible, depending on the size of the transfer operation, that there would not be enough property available here to operate it and I believe the State Highway Department has also put some restrictions on the number of cars that can use this yard area since the entrance and exit to it is immediately off a ramp to the Freeway. It's worth looking into further, however, and there may be another site in this immediate area that would also be suitable.

The sites mentioned above are either tax forfeited property or are in the City's name and would be reasonably easy, possibly, for the City to acquire them. We don't feel that this search should be limited to only this type of property, and we should also be looking at locations that are privately owned now and, of course, would have to be purchased. In my judgment, I-94 which runs through the whole middle section of St. Paul from east to west would be a "key" in looking for a site. I think all property along the Freeway should be looked at since undoubtedly the transfer trucks themselves would be using the Freeway out east into Washington County.

IV. FINANCING AND METHOD OF OPERATION OF TRANSFER STATIONS. Along with the determination of how many stations should be considered and their locations, another very important factor to the City is the method of financing and operation that is chosen. Should it be financed through general revenue bonds and operated by the City on a fee basis, should it be financed and built entirely by private industry, or just what method of operation should be chosen. We have listed a number of ideas on this subject:

A. TO BE CONSTRUCTED AND OPERATED ENTIRELY BY PRIVATE INDUSTRY.

The City of St. Paul would specify the exact locations and furnish the property and specify the size of the station and the general type, however, from that point on, the private industry would completely design, construct, and operate the facility. Rates would be subject to ~~negotiation~~ regulation by the City Council.

B. TO BE FINANCED BY THE CITY OF ST. PAUL THROUGH THE SALE OF REVENUE BONDS WITH THE BONDS TO BE PAID OFF BY THE USER FEE.

1. "In-house" design and construction by the Department of Public Works and the operation by City forces. User fees would

be set up similar to our present landfill operation to pay off the revenue bonds in, say, a 10-year period.

2. The City to specify the location of transfer facilities and have private consulting firm design and construct the transfer stations and turn them over to the City to be operated by City forces. User fees would be charged. This is the standard "turn-key" approach.

3. Same as #2, except carry it one step further. Private firm design, construct and operate the facility. User fees required by City, but contract to be awarded on basis of low figure, dollars/ ton of refuse disposed. This figure would then be paid to the City for every ton of refuse disposed at the station to pay off the revenue bonds.

SOME RANDOM THOUGHTS:

1. It's doubtful that the P. C. A. will budge from the Pig's Eye closing date of July 1, 1972. Therefore, it's crucial that plans for at least one large transfer facility proceed with all due speed. Seven months to locate, design, and construct a facility is "shaving it very close".

2. The biggest problem will be to educate our citizens and elected officials as to the need for the transfer stations. Once the need is recognized and the financing provided, it's no great problem to design and construct them.

3. Any plans for transfer facilities should include provisions to separate metals, glass, paper, etc. may not be incorporated immediately but space must be provided to expand into recycling.

4. We are preparing a survey of all transfer facilities in the Metropolitan Area. Locations, sizes, types, hours of operations, and fees will be recorded. We will also prepare a slide presentation of the existing facilities.

5. Once the idea of transfer stations has been established with our citizens and public officials, but before we start designing the actual facilities, that a representative of the Public Works Department and a representative of the private hauling industry make a close field inspection of two or three of the most modern transfer stations in the country. A.P.W.A. in Chicago can give us a listing. A report would then be prepared outlining the most up-to-date features and thinking that should be included. In my judgment this should precede the selection of a consultant or any of the technical work.

01398

DOCUMENTS RELATING TO:

THE METROPOLITAN WASTE
CONTROL COMMISSION (EXHIBIT C.2)

2/28/73

PCA Seeking to End Dumping at Pig's Eye

By DON BOXMEYER
Staff Writer

Refuse from the Metropolitan Sewer Board's Pig's Eye treatment plant is being dumped in that area — just a stone's throw from the St. Paul landfill that was closed by the state eight months ago.

MAYOR LAWRENCE Cohen said his office will order the sewer plant to "clean up" the dump over the weekend or else face an injunction in Ramsey District Court Monday morning.

Assistant City Attorney Dan Ficker said the dump "is a defi[illegible] ard on p[illegible] land is own[illegible] by the sewer board, [illegible] governmental agency), and must be rectified" by eith[illegible] the piles of [illegible] covering them over with clean material.

After Minnesota Pollution Control Agency (PCA) engineers viewed the "grit and screenings" disposal area Tuesday, they termed it a "dump" which "does not meet the criteria of a sanitary landfill."

THE PCA ENGINEERS inspected the disposal site — in the thick brush of the Mississippi River floodplain just east of the treatment plant — after the Dispatch inquired whether the Sewer Board had a dumping permit.

Following the inspection, PCA staff engineer Mike Zagar said he will recommend that the material from the sewage plant be disposed of elsewhere.

"It goes without saying that the material should not be there," Zagar said. "It certainly is not environmentally acceptable."

THE ST. PAUL Pig's Eye landfill was ordered closed last July 1 by the PCA because while the operation was a sanitary landfill, the area was within the river's floodplain. The treatment plant's disposal area is also within the floodplain.

After the Dispatch discovered the site Monday, sewer plant officials said the area was used only for depositing inorganic "grit" in the form of sand and dirt that enters the sewage plant and is separated from the organic effluent, and "screenings" in the form of paper, rags, wood, and other untreatable refuse caught before it enters the plant.

But the disposal area is also littered with garbage bags, large boxes, tires, 55-gallon drums, refuse, garbage cans, fiber drums and other refuse which obviously was not screened from the sewers.

ON TUESDAY, a Metropolitan Sewer Board dump truck was observed and photographed dumping a load of cans, rags, paper, wood, food wrap-

Turn to Page 18, Col. 1

~~Bub~~ JE ~~LS~~ BA ~~GHB~~ LGAT ~~DJK~~ LBS

PCA Seeks to End Dumping

Continued from Page 1

pers and other [illegible] refuse at the site.

Later that day, Dr. Eugene Garner, plant superintendent, said refuse from the plant is sometimes dumped at the site if it is "similar to what is caught in the screens."

Zagar, after inspecting the site, said, "You could call it a dump." A colleague, Bruce Brott, said the site "would not meet the criteria for a landfill" because refuse in a landfill is covered with at least six inches of dirt at the end of each dump day.

With the enforced closing of Pig's Eye Landfill, there are no landfills left in St. Paul.

The Sewer Board dump, to the south of the old Pig's Eye site, is surrounded by ash disposal ponds which Zagar says his agency "also frowns upon."

After sewage is treated, the sludge is incinerated at the plant. The ash residue from the incinerator is piped to the disposal lagoons — also in the river's floodplain.

While plant officials conceded that much of the refuse dumped at the site comes from the plant, they blamed the "minimal" plant security for allowing "illicit dumpers" in from the outside to discard their waste.

A RAILROAD crossing-type bar at the plant entrance was knocked out of commission several months ago and has not been replaced to prevent afterhour "tours" of the sewage plant.

Meanwhile, sources in the St. Paul Public Works Department were concerned that if the PCA orders an end to the on-site disposal of [illegible] and screenings, the Metro Sewer Board may have a [illegible] finding a landfill which will accept the material.

Metropolitan Sewer Board
OF THE TWIN CITIES AREA

File

01401

Pigs Eye

524

350 Metro Square Building, 7th & Robert Street, Saint Paul, Minnesota 55101 Area 612, 222-8423

December 10, 1974

Mr. Robert A. Silvagni, Director
Division of Solid Waste
Minnesota Pollution Control Agency
1935 W. County Road B-2
Rosville, Minnesota 55113

Subject: Permit Nos. 8292 and 8293 for Metro Plant Projects 71-06 and 71-07

Dear Mr. Silvagni:

This is our report to the MPCA on the disposal of waste material under the above permits for the month of November as requested in your letter to the Metropolitan Sewer Board dated November 7, 1974.

Disposal for the projects was as follows:

Project 71-06 - Pretreatment Facilities (Permit No. 8293)

Type and Quantity - Approximately 26,500 cubic yards of ash material
Origin - Subcut excavation (see attached photo)
Disposal Location - Port Authority property (see attached photo)

Black topsoil mixed with silt is stockpiled on Project 71-06 site

Project 71-07 - Primary Tanks (Permit No. 8292)

Type and Quantities - 7,500 cubic yards black topsoil
3,800 cubic yards topsoil mixed with silt and sand
33,000 cubic yards ash mixed with silt
Origin - Subcut excavation (see attached photo)
Disposal Location - Black topsoil - stockpiled on Project 71-07 site
Topsoil mixed with silt and sand - hauled to Project 71-04
Ash mixed with silt - hauled to Port Authority property (see attached photo)

2000087

Disposal of waste material from the above projects is in accordance with the letters from MPCA as follows:

1. Hugh L. McConnell to Kraus-Anderson Construction Co. dated November 27, 1974;

2. Hugh L. McConnell to Kraus-Anderson Construction Co. dated November 29, 1974;

3. Hugh L. McConnell to Metropolitan Sewer Board dated December 6, 1974; and

4. Field inspection and review of waste disposal by Hugh L. McConnell and K. Larson of MPCA and Metropolitan Sewer Board, and contractor representatives, December 6, 1974.

Disposal operations will continue as per current procedures and will be reported monthly

Yours very truly,

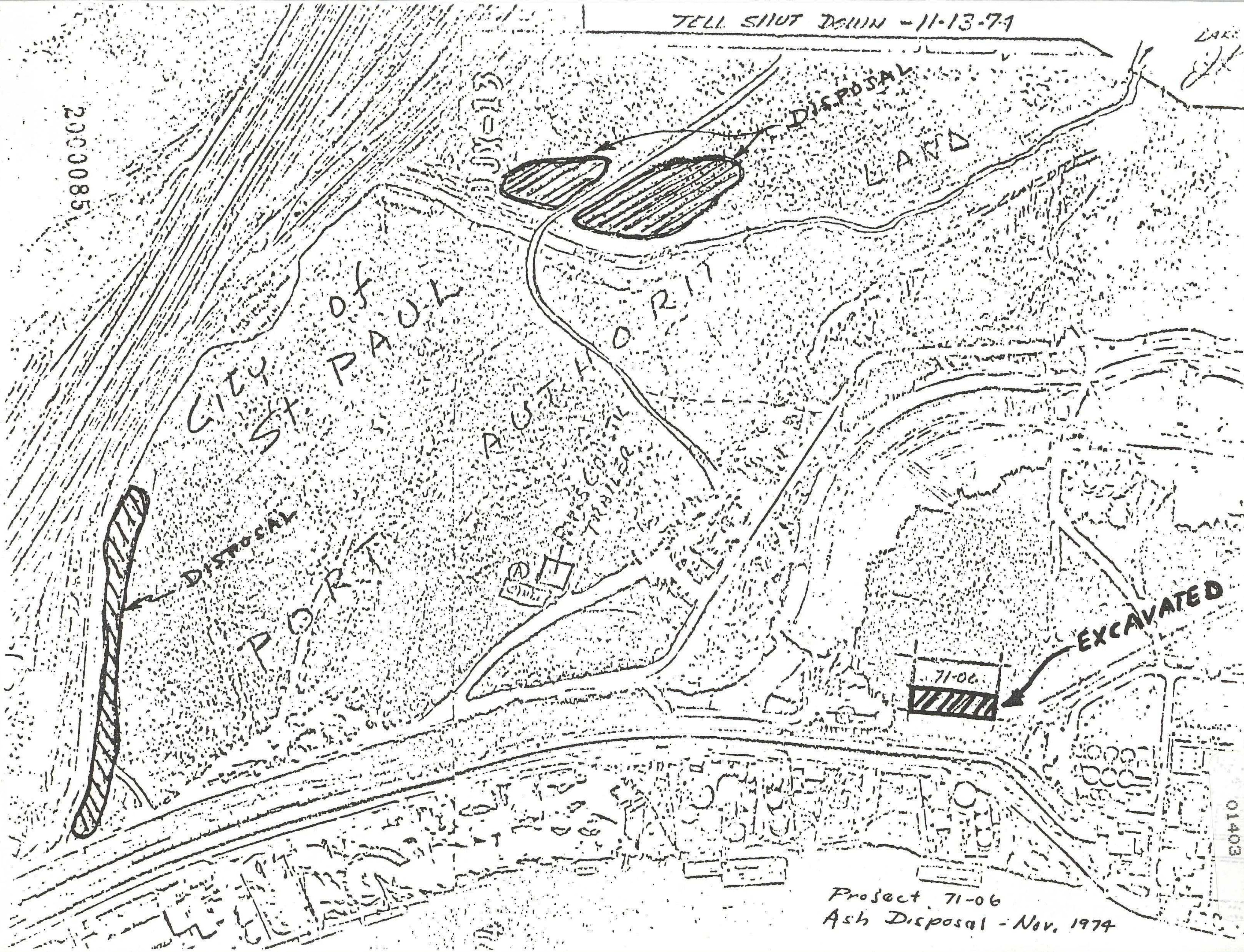
METROPOLITAN SEWER BOARD

Richard J. Dougherty
Chief Administrator

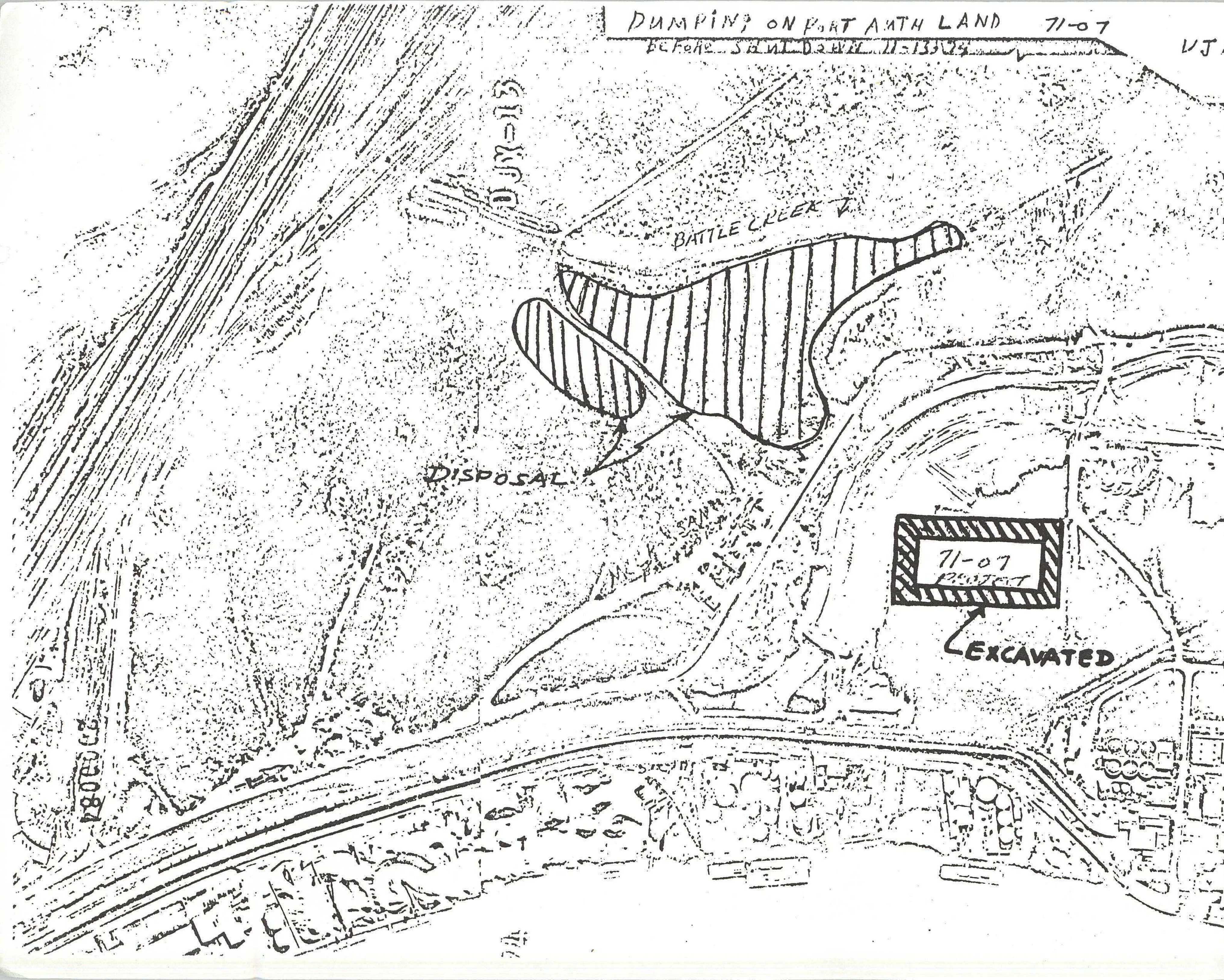
RJD:ROF:sil

Enclosures

CC: S. E. Linsley, MWWTP
Walter VanderBorght, Resident Engineer, MSB
Ken Foster, Resident Engineer, MSB
R. O. Folland, Chief Construction Engineer, MSB
Lonnie E. Dye, Chief Engineer, MSB
Donald Eichers, Staff Engineer, MSB



Project 71-06
Ash Disposal - Nov. 1974


DUMPING ON PORT AUTH LAND
71-07
VJM
BATTLE CREEK
DISPOSAL
71-07
EXCAVATED

File - #524

01405

CITY OF SAINT PAUL

DEPARTMENT OF PUBLIC WORKS

DANIEL J. DUNFORD
DIRECTOR

October 16, 1975

Mr. Gary A. Pulford, Chief
Section of Enforcement
Solid Waste Division
Minnesota Pollution Control Agency
1935 West County Road B-2
Roseville, Minnesota 55113

RE: City of St. Paul Pig's Eye Landfill Site

Dear Mr. Pulford:

This will confirm the discussions between you and Messrs. Scott Gilbertson and Michael Eggum from this office at the Pig's Eye Landfill site on October 10, 1975. You had made a previous inspection a little over a month ago and submitted a letter to us dated September 5, 1975 wherein you indicated additional work was required before the landfill could be certified as closed. The Department of Public Works has arranged for considerable work on the site over the past several weeks and we believe that all of the points covered in your letter have now been taken care of. Mr. Gilbertson indicated to me that, based on your inspection, you also felt that the site now meets the requirements with the one exception of the seeding.

There will be additional filling done over the next few months and, also, into the spring of 1976. The Department of Public Works will make arrangements to seed the entire site once the filling is completed. We will use a rye seed applied at the rate of 100# per acre as specified in Section 3876 of the Minnesota Highway Department specifications.

The Bolander Construction Company is doing the excavation work at the Metropolitan Waste Water Treatment Plant. It was estimated when they started that approximately 200,000 cubic yards of fill would be disposed of on the landfill site. We understand that Bolander is about half complete with this excavation contract and the balance should be finished up within the next month or two. We have marked the area in red on the attached drawing where Bolander will dispose of additional material this fall.

We believe that there is now adequate fill material over the site to comply with the regulations but we have been advised that there will be another excavation contract at the Metropolitan Waste Water Treatment Plant next spring. We have requested through Mr. Clifford Ramsted, Chief Engineer for the St. Paul Port Authority, that the landfill site be designated as the disposal site in that contract so there will be a considerable quantity of fill added next year.

We are now processing the necessary forms to register the landfill site with Ramsey County as required by the law and we will forward a copy of it to you once it is completed.

2000096

01406

METROPOLITAN
WASTE
CONTROL
COMMISSION
Twin Cities Area

NOV 9 1977
MINN. POLLUTION
CONTROL AGENCY

November 9, 1977

Mr. Bruce Brott
Minnesota Pollution Control Agency
1935 West County Road B2
Roseville, MN 55113

Subject: Metro Ash Disposal Project

Dear Mr. Brott:

We have performed additional leachate tests on ash from the Metropolitan WWTP to determine chromium values. The values determined are listed below:

	Total Chromium (mg/l)
W_1	7.5
W_2	1.15
A_1	13.0
A_2	4.05

It appears that leachate levles for chromium are consistently in the range of 2.0-9.0 mg/l for W_1 values and 1.0-2.0 mg/l for W_2 values. Although these levels are higher than ash pond discharge values, it is our opinion that leaching will be minimized by soil cover, vegetative cover, and gradation.

It should be noted that although chromium levels may exceed drinking water standards, the existing groundwater is of poor quality and would never be considered as a public water source. Chromium is only a health concern in the hexavalent state, however, with time the hexavalent form is reduced to the more stable trivalent form. Trivalent chromium is of low toxicity to both plants and animals and should not present a problem at the levels indicated in the leachate test.

Martin

In summary, the combination of factors mentioned above mitigate the potential impacts of chromium leaching. We again request that immediate action be taken towards issuance of required action. We will assist in any possible manner to expedite this process.

Very truly yours,

Bernard J. Harrington

Bernard J. Harrington
Director of Engineering

BJH:WGM:bdw

METRO SQUARE BLDG.
7TH & ROBERT STREETS
SAINT PAUL MN 55101
612 222-8423

1000442

Table 1
CHEMICAL CHARACTERISTICS OF METRO PLANT SLUDGE INCINERATOR ASH

Parameter	Concentration October 1977[a] (mg/ kg)	November 1977[b] (mg/ kg)
Ag	—	77
Al	—	29,700
Ba	—	166
Ca	—	242,000
Cd	47	50
Co	—	20
Total Cr	2,824	1,180
Cu	2,170	1,820
Fe	—	15,100
Hg	0.11	Negligible
Mg	—	12,600
Mn	—	233
Ni	533	96
Pb	571	60
Zn	2,548	1,070
pH	—	10.75

a Grab sample of ash collected and analyzed by the MWCC.

b Grab sample from ash lagoon collected and analyzed by CH2M HILL.

METROPOLITAN
WASTE
CONTROL
COMMISSION
Twin Cities Area

Mw.c A.. 01408

RECEIVED
NOV 21 1977
MINN. POLLUTION
CONTROL AGENCY

November 21, 1977

Mr. Bruce Brott
Minnesota Pollution Control Agency
1935 West County Road B2
Roseville, MN 55113

Subject: MWWTP Ash Disposal

Dear Mr. Brott:

At your request, the Commission has run an additional leachate test on ash from the Metropolitan Wastewater Treatment Plant to determine chromium values in the leachate. The results are listed below:

	Total Cr	Hexavalent Cr
W_1	7.0	6.3
W_2	0.60	0.52
A_1	9.2	7.8
A_2	3.35	0.08

The results from the tests were discussed in detail with the Agency staff on November 18, 1977. At that time, Dr. Hoffman from the University of Minnesota presented a substantial amount of information concerning the fate of chromium in the ash leachate. The information and conclusions are contained in the attached report entitled "Fate of Chromium Leached from Fly-Ash Residue Dumped on an Old Sanitary Landfill". The conclusion of the report is that any hexavalent chromium present in the leachate should be reduced to trivalent chromium under the existing conditions of the landfill. Furthermore, the predicted half-life for hexavalent chromium in the presence of excess reducing agents is from 3 to 30 minutes. Even under conditions where reductant concentrations are low, the half-life for hexavalent chromium is predicted to range from 29 minutes to 8 days. Given the high amount of organics present in the groundwater (200-300 mg/l COD) and adequate detention time, hexavalent chromium should readily be converted to the trivalent form.

As you are aware, Soil Exploration Service attempted to determine groundwater movement rates in 1974. Their conclusion was that groundwater movement in the landfill area was very slow (i.e. no movement was determined in a 2 month study). The existing groundwater conditions indicate that more than adequate detention time will be available for chromium reduction.

350 METRO SQUARE BLDG.
7TH & ROBERT STREETS
SAINT PAUL MN 55101
612 222-8423

As indicated at the November 18 meeting, the Commission has adequately addressed all questions concerning the project. It is urgent that a permit be issued in November since the ash pond discharge is in danger of failing NPDES Standards. Please contact us if we can be of any further assistance in expediting issuance of the permit.

Sincerely,

Bernard J. Harrington
Bernard J. Harrington
Director of Engineering

BJH:WGM:kla
Attachment

cc: R. J. Dougherty, Chief Administrator, MWCC
G. W. Lusher, Director of Operations, MWCC
W. K. Johnson, Director of Quality Control, MWCC
Dan Comeau, MPCA
Fred Jenness, MPCA

01409

New? F'e MWCC Ash Disposal Site"

Report Prepared for the

Metropolitan Wastewater Control Commission

and the

Minnesota Pollution Control Agency

"Fate of Chromium Leached from Fly-Ash Residue Dumped on an Old Sanitary Landfill"

by

Dr. Michael R. Hoffmann
Assistant Professor
Environmental Engineering Program
Department of Civil & Mineral Engineering
University of Minnesota
Minneapolis, Minnesota 55455
612-373-2514

Attention: Dr. Walter K. Johnson

Fate of Chromium Leached from Fly-Ash Residue Dumped on an Old Sanitary Landfill

This report has been prepared in response to the request of the Metropolitan Waste Control Commission and the Minnesota Pollution Control Agency for a quantitative prediction of the fate of hexavalent chromium leached through an anaerobic sanitary landfill with a high COD leachate. This report consists of three distinct sections in which the thermodynamic behavior, kinetic behavior and predicted fate of chromium is examined with the aid of equilibrium computer calculations and kinetic analyses based on literature data.

The conclusion reached, after careful quantitative analysis, is that hexavalent chromium should be reduced to Cr(III) given the prevailing low oxidation-reduction potential of the combined fly-ash/sanitary landfill leachate. The calculated half-lives, $t_{1/2}$, for CRO_4^{-2} in the presence of excess reducting agent (i.e. oxidizable organics, Fe(II), HS^-, cysteine) have been calculated to range from 3 to 30 minutes based on pseudo-first order kinetics; and when the reductant concentrations are low [reductant] = [$CrO_4^=$], the half-lives have been calculated to range from 29 minutes to 8 days based on pseudo-second order kinetics. Considering that the residence time (τ_r^-) of the groundwater in the sanitary landfill is immeasureably long, it is reasonable to assume that most of the hexavalent Cr will be reduced to the less toxic Cr(III). The rate of oxidation of CrIII to CrVI by oxygen is immeasureably slow at room temperature (Schoeder and Lee), so that little, if any, Cr(III) would be converted back to CrO_4^{-2}; Cr(III) would be primarily in the solid form at pH8 or adsorbed on colloidal solids with negative charge.

Physical-Chemical Forms of Cr in Sewers, Treatment Facilities and Aquatic Systems

Chromium enters sewers in both the hexavalent form, Cr(VI) and in the trivalent form Cr(III). Uses contributing CrVI are well-known, e.g., algicidal applications, corrosion inhibitors, and other industrial uses.

Cr(VI) will tend to exist predominantly as the soluble ion $HCrO_4^-$ at pH8 for concentrations of a few mg/l or less. $HCrO_4^-$ can also be adsorbed on colloidal solids with a positive charge.

Cr(III) is expected to exist in at least three principal forms at pH8: the solid $Cr(OH)_3(S)$, the cation $Cr(OH)_2^+$, and the anion $Cr(OH)_4^-$. The maximum equilibrium solution concentration of the two ions combined at pH8 is near 0.02 mg/l. Thus, at the levels of chromium reported in sewage, one expects most Cr(III) to exist as the solid $Cr(OH)_3(S)$. The CrO_4^{-2} ion is a reasonably strong oxidant at pH8; therefore, reductants such as sulfide, Fe(II), sugars, alcohols, and many other organic compounds are capable of reducing CrO_4^{-2} to Cr(III). The resulting form of Cr(III) should be $Cr(OH)_3(S)$ as a reduction product.

Two other general chemical forms of Cr(III) may be expected: Cr(III) adsorbed on particles in wastewater and Cr(III) existing in solution as a soluble chelated complex with organic matter.

It is reasonable to assume that chromium entering a wastewater system as Cr(III) will precipitate as $Cr(OH)_3(S)$ or become adsorbed on particulates. Chromium entering as Cr(VI) experiences a strongly reducing environment in the sewers and treatment plants (little to no dissolved O_2) and as a consequence becomes reduced to Cr(III), then tending to precipitate or adsorb. There should be much less Cr(VII) at the treatment plants than originally entered the sewer system upstream.

Discharge of wastewater effluent into aquatic systems may result in solubilization of $Cr(OH)_3(S)$ and desorption of Cr(III) attached to particulates, depending on the degree of dilution. In well-oxygenated rivers, Cr(VI) would be largely unaffected.

Thermodynamic Analysis of Predominant Chromium Species as a Function of Redox Potential

REDEQL2 (Morel and Morgan, see copy in appendix), a complex computer program for the computation of chemical equilibria in environmental systems, was used to calculate the predominance of either Cr(III) or Cr(VI) as a function of redox level. From preliminary leaching tests on fly ash, it was determined that a maximum concentration of Cr of 9.2 mg/l was released in the first 200 ml fraction of acidic leachate. This value of Cr was used to calculate the species distribution as the system was varied from reducing to oxidizing conditions. The species considered were $Cr(OH)^{+2}$, $Cr(OH)_2^+$, $Cr(OH)_4^-$, Cr^{+3}, $Cr_2O_7^{-2}$, $HCrO_4^-$ and $CrO_4^=$. These species are interrelated by the following equilibria:

(1) $HCrO_4^- \rightleftarrows CrO_4^{-2} + H^+$ pK = 5.9

(2) $H_2CrO_4 \rightleftarrows HCrO_4^- + H^+$ pK = 0.61

(3) $Cr_2O_7^{-2} + H_2O \rightleftarrows 2HCrO_4^-$ pK = 2.2

(4) $Cr_2O_7^{-2} + 14H^+ + 6\bar{e} \rightleftarrows 2Cr^{+3} + 7H_2O$ E° = 1.33v

(5) $Cr_2O_7^{-2} + 4H_2O + 3\bar{e} \rightleftarrows Cr(OH)_3 + 5OH^-$ E° = -.13v

(6) $HCrO_4^- + 7H^+ + 3\bar{e} \rightleftarrows Cr^{+3} + 4H_2O$ E° = 1.19v

(7) $CrO_4^{-2} + 4H_2O + 3\bar{e} \rightleftarrows Cr(OH)_3 + 5OH^-$ E° = 0.12v

Species distributions were calculated for pH values of 2, 4, 6, 8 and 12.

Results are depicted in Figures 1-5. The negative logarithm of the molar concentration of each species is plotted as a function of pε, negative logarithm of the electron activity. A pε of 12 is strongly oxidizing whereas a pε of -6.0

is strongly reducing. At low pH, Cr would be predicted to exist as CrIII over the entire range of pε considered. In order for CrVI to exist at low pH, a stronger oxidizing system is needed. At pH10, Cr(VI) will be readily reduced in mild oxidizing systems. Most Cr(VI) is converted to Cr(III) below pε 4.0. At pH8 most Cr(VI) is converted to Cr(III) below pε 8. From the trends indicated in Figures 1-5, it can be predicted that Cr(VI) should be reduced readily in the presence of reducing agents but the particular aquatic system must be more reducing (anoxic) at higher pH values.

Kinetic Analysis of the Reduction of Cr(VII) by Fe(II), Sulfide and Cysteine

Data published by Schroeder and Lee (1975), see copy in appendix on the reduction of CrO_4^{-2} by Fe^{+2}, HS^- and cysteine ($NH_2HC(CH_2SH)COOH$). Their results indicate that CrO_4^{-2} is fairly rapidly reduced by HS^-, Fe^{+2} and cysteine. From raw data, pseudo order rate constants can be determined by two methods. The first method is to graphically estimate the half-life and determine the pseudo first-order rate constant from equation 10.

(8) $\ln c/C_o = -kt$

(9) $\ln 2 = k't\ 1/2$

(10) $k' = 0.693/t\ 1/2$

The second method assumes that the slope of a least-squares fit of lnC versus time will yield the pseudo first-order rate constant. Schroeder and Lee's data has been treated accordingly and the results are depicted in Figures 6-8.

From evidence presented by Schroeder and Lee it appears that the reductions are at least second-order with a concentration dependence on [CrVI] and [Reducing Agent]. A half-life based on pseudo second-order kinetics can be calculated in the following manner:

(11) $-d[CrO_4^{=}]/dt = k[CrO_4^{=}]\,[Fe(II)]$

(12) $k_{obs} = k[FeII]$ when

$[FeII] >> [CrO_4^{=}]$

(13) $k_{obs} = -d[CrO_4^{=}]/[CrO_4^{=}]/dt$

(14) $k = k_{obs}/[FeII]$

(15) $t\ 1/2 \cong 1/k\,[CrO_4^{=}]$ for $[Fe(II)]^{=} \cong [CrO_4^{=}]$

In most experiments, Schroeder and Lee used an excess of reducing agent so that $[FeII] > [CrO_4^{=}]$. When $[reductant] >> [CrO_4^{=}]$ first-order half-lives would be appropriate and when $[reductant] \cong [CrO_4^{=}]$ a second-order half-life should be used.

Table I

Predicted Half-Life/First-Order Kinetics Reduction of CrO_4^{-2}

Reductant	t 1/2 (minutes)
Fe(II)	3
HS^-	5 (graphically)
Cysteine	28

Table II

Predicted Half-Life/Second-Order Kinetics Reduction of CrO_4^{-2} (0.4 mg/l)

Reductant	t 1/2 (hours)
Fe(II)	0.5
HS^-	35 (graphically)
Cysteine	192

Models for Fate of Trace Metals Discharged in the Aquatic Environment

Morel et al. (1975, copy included in appendix) have used REDEQL to predict the fate of trace metals in Los Angeles County Wastewater Discharge. Similar models can be developed for the trace metals present in the effluent from the fly ash ponds. A complete model was developed using the January 1976 monthly averages for metal concentrations and typical values of anion concentrations from the wastewater effluent averages over the year. Sample output is included in the appendix. Depicted in Figure 9 is the % Total Metal for Cr plotted against pε at pH 9.5, the pH of the pond effluent. The predominant Cr species are $Cr(OH)_4^-$ at low pε. There appears to be little effect of negatively charged adsorbing surface (α-SiO_2). Cr(III) and Cr(VI) would both be present as soluble species in the pond effluent.

References

1. Schroeder, D. C. and G. F. Lee, "Potential Transformation of Chromium in Natural Waters," Water, Air and Soil Poll., 4, 355-365 (1975).

2. Morel, F. and J. Morgan, "A Numerical Method for Computing Equilibria In Aqueous Chemical Systems," Environ. Sci. Tech., 6, 58-67 (1972).

3. Morel F. M. M., J. C. Westfall, C. R. O'Melia, and J. J. Morgan, "Fate of Trace Metals in Los Angeles County Wastewater Discharge," Environ. Sci. Tech. 9, 756-761 (1975).

FIGURE 1

CONCENTRATION OF CR SPECIES AS A FUNCTION OF PE AT PH 10

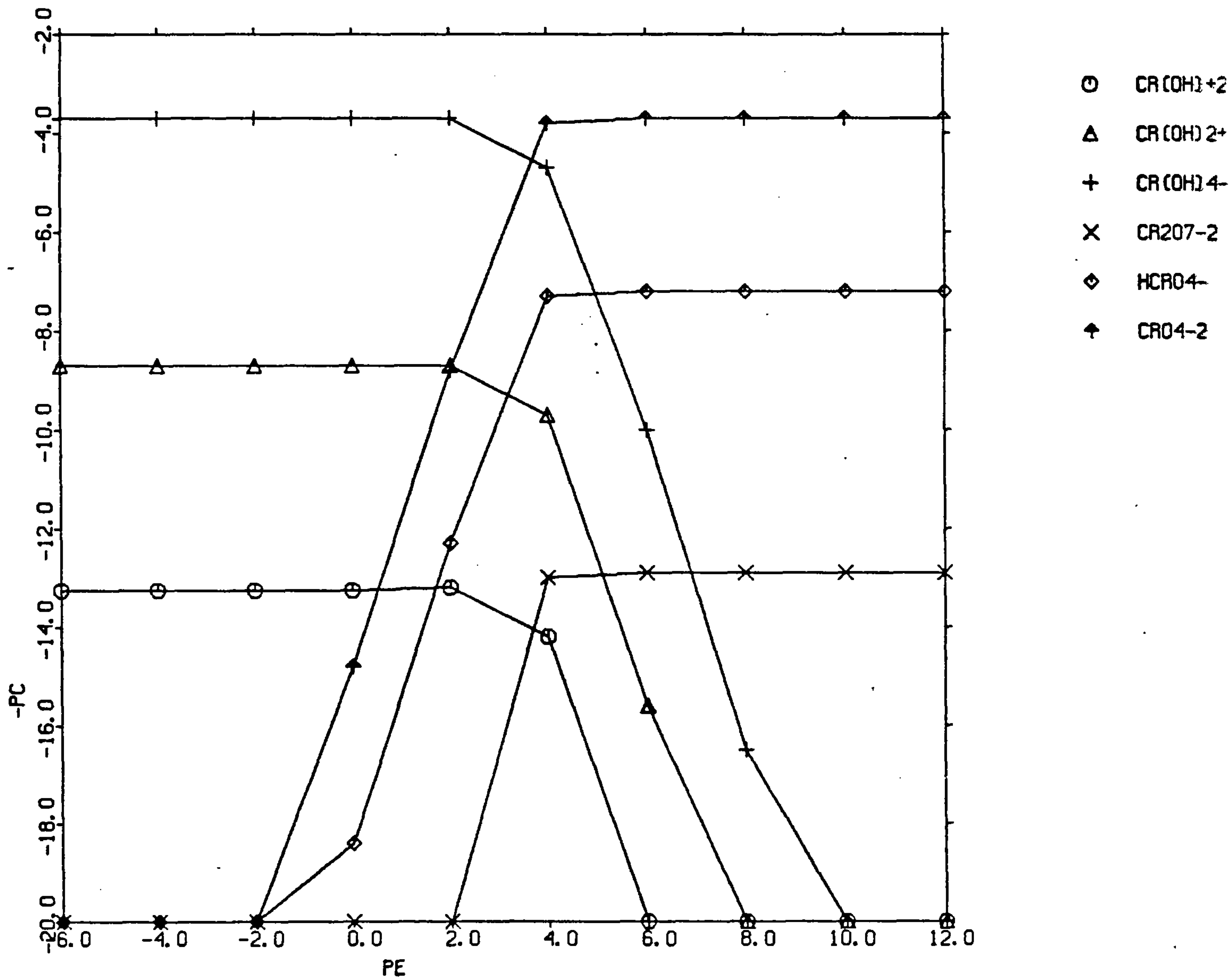


FIGURE 2

CONCENTRATION OF CR SPECIES AS FUNCTION OF PE AT PH 8

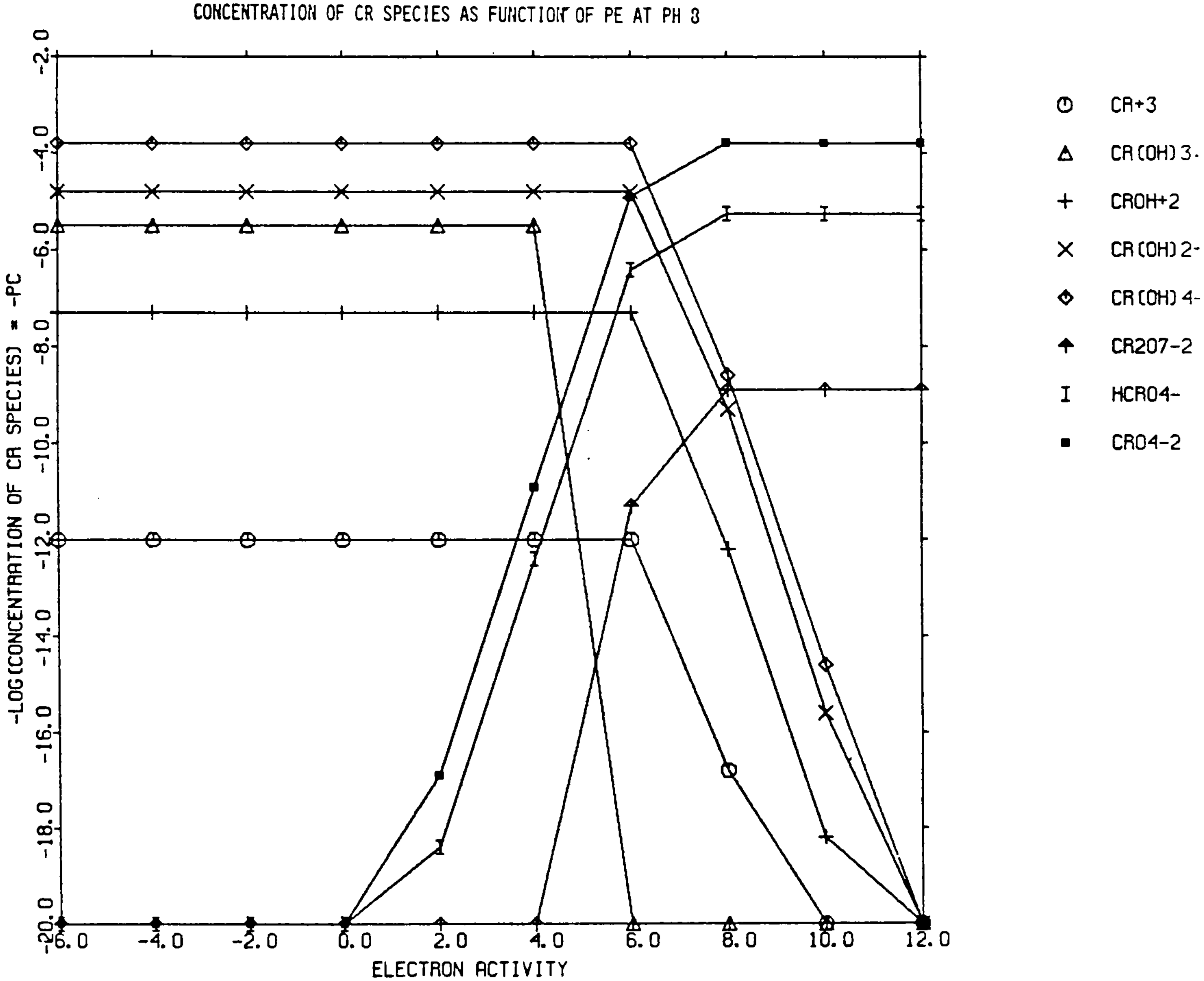


FIGURE 3

CONCENTRATION OF CR SPECIES AS A FUNCTION OF PE AT PH 6

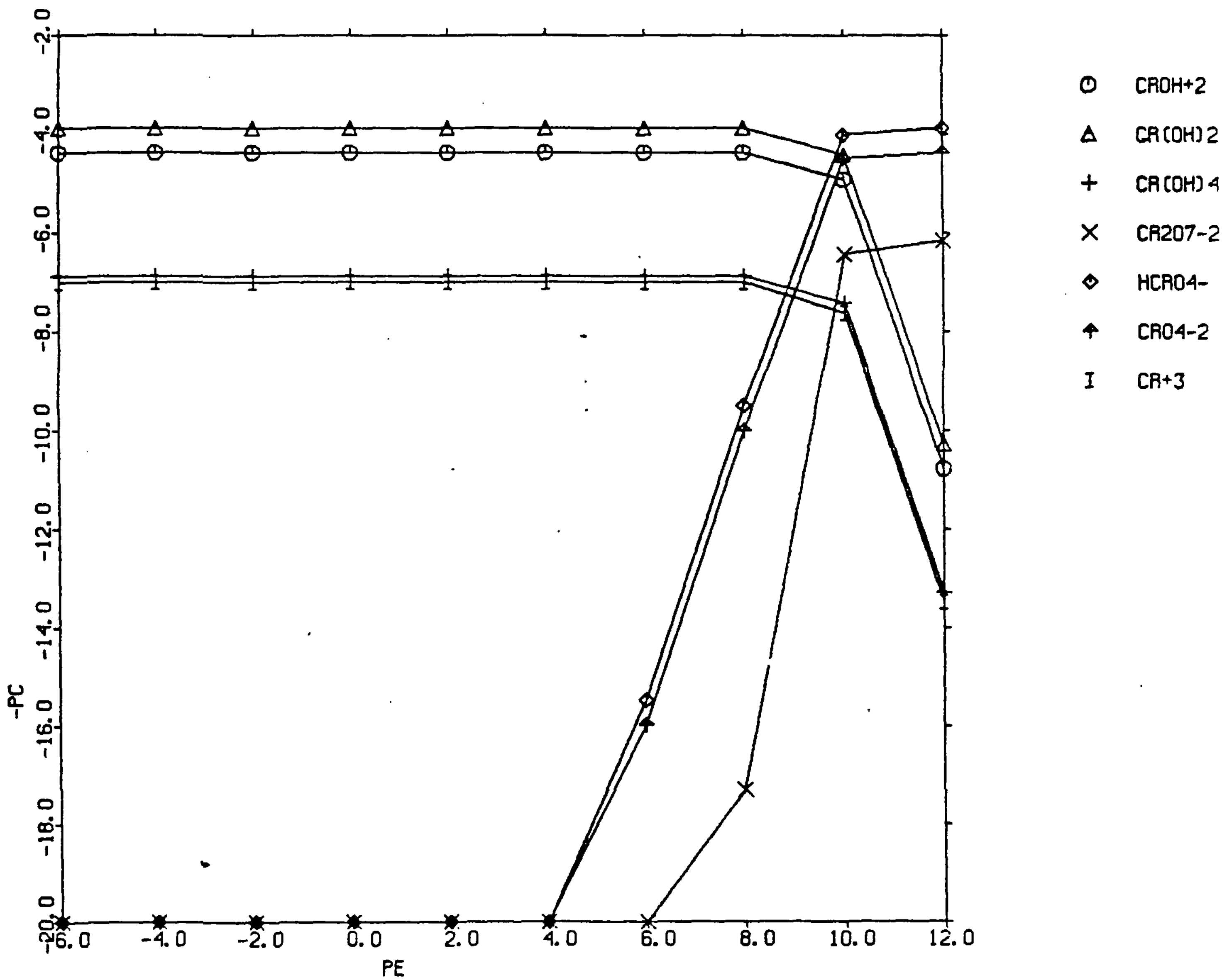


FIGURE 4

CONCENTRATION OF CR SPECIES AS A FUNCTION OF PE AT PH 4

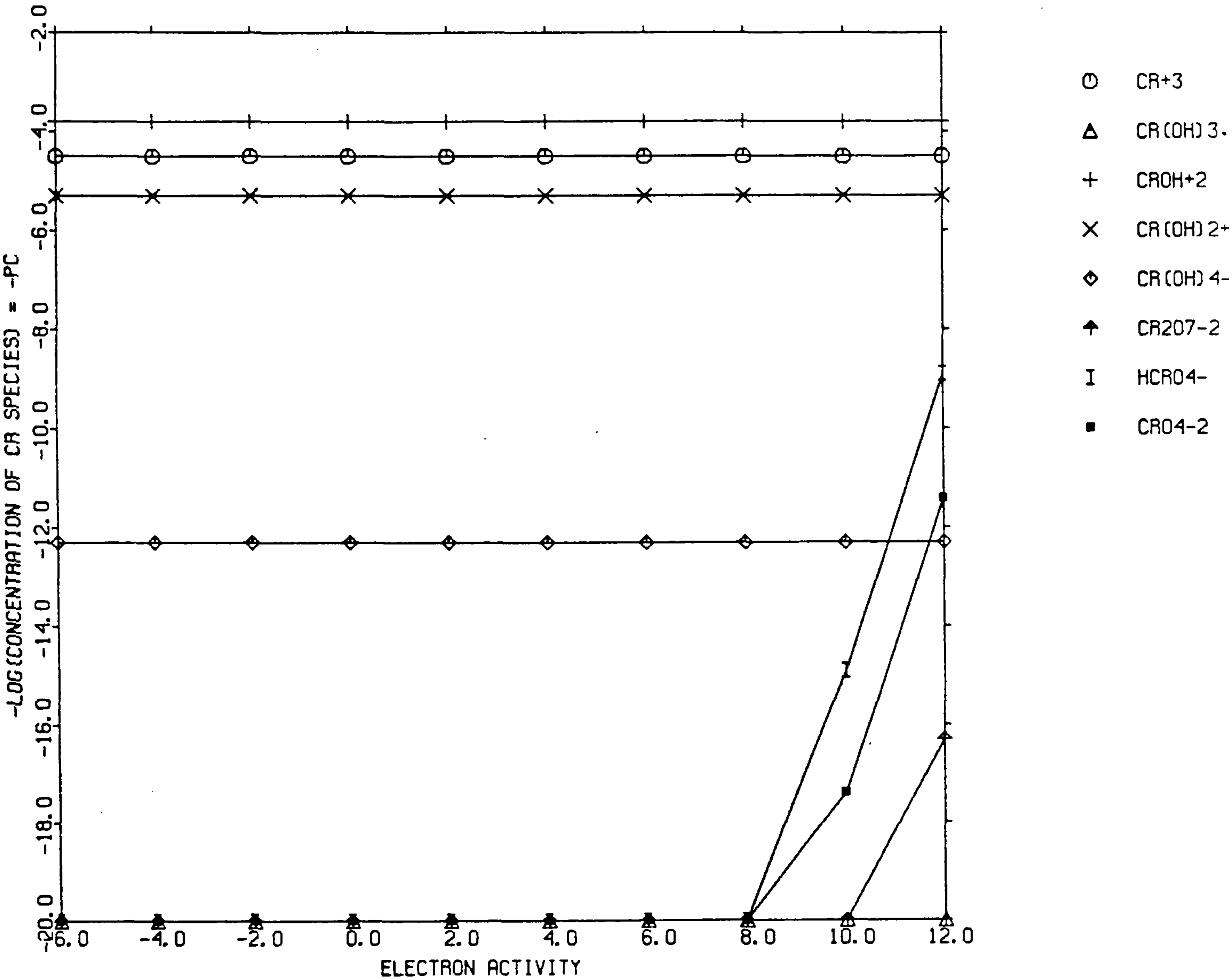
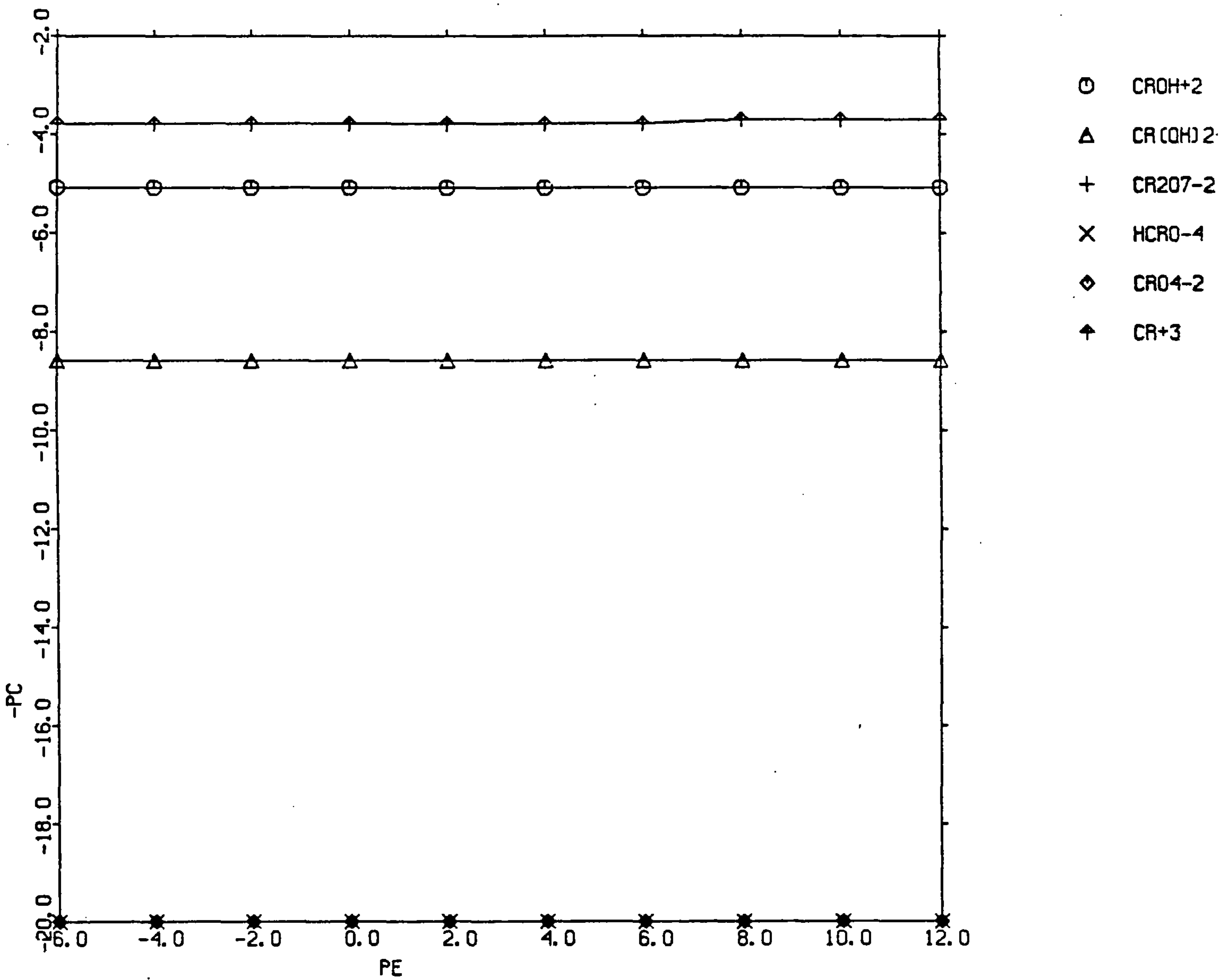


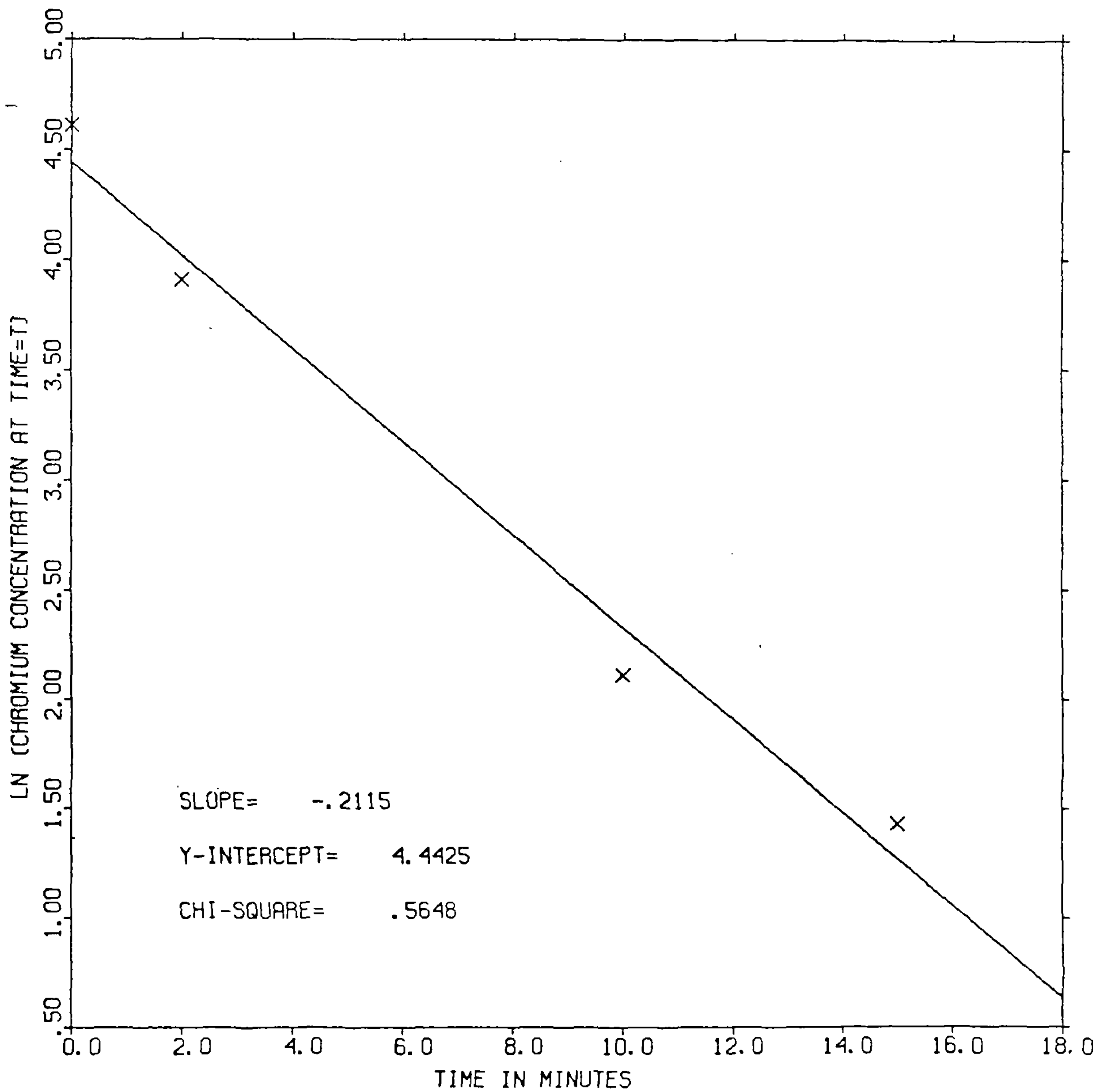
FIGURE 5

CONCENTRATION OF CR SPECIES AS A FUNCTION OF PE AT PH 2



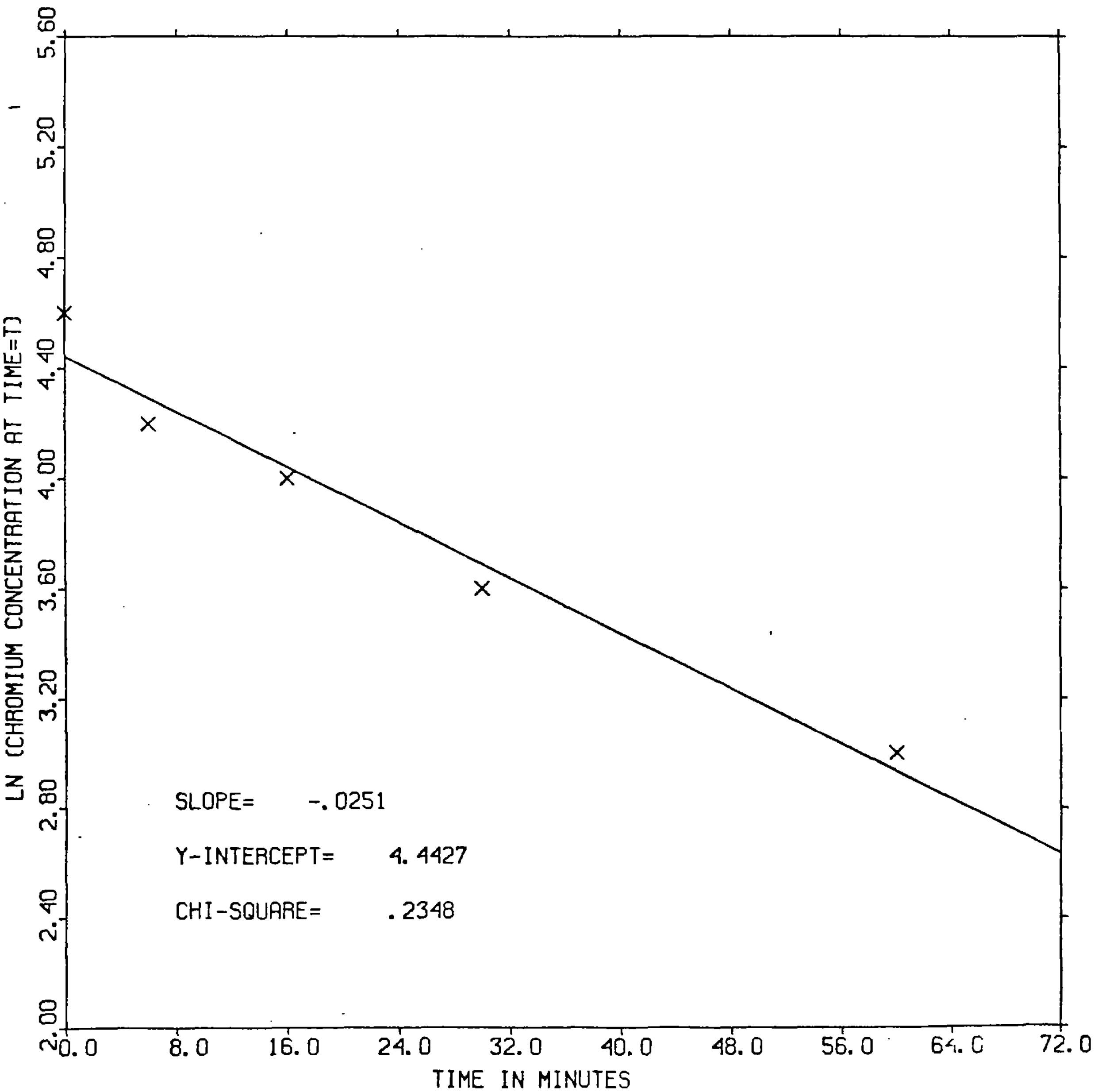
CASE NUMBER 1 FIGURE 6

FIRST-ORDER KINETIC PLOT FOR CR(VI) AND FE(II)



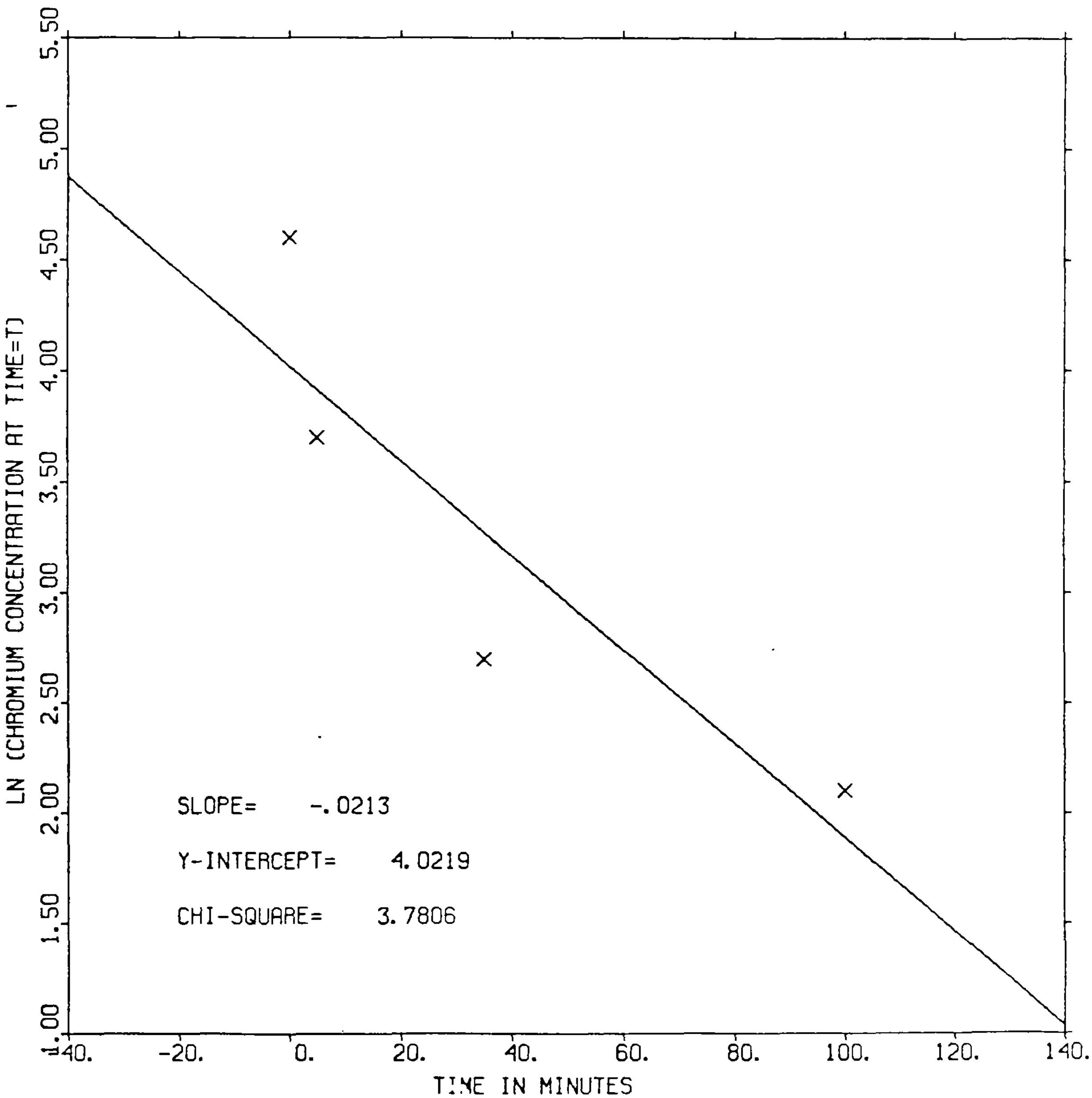
CASE NUMBER 2 FIGURE 7

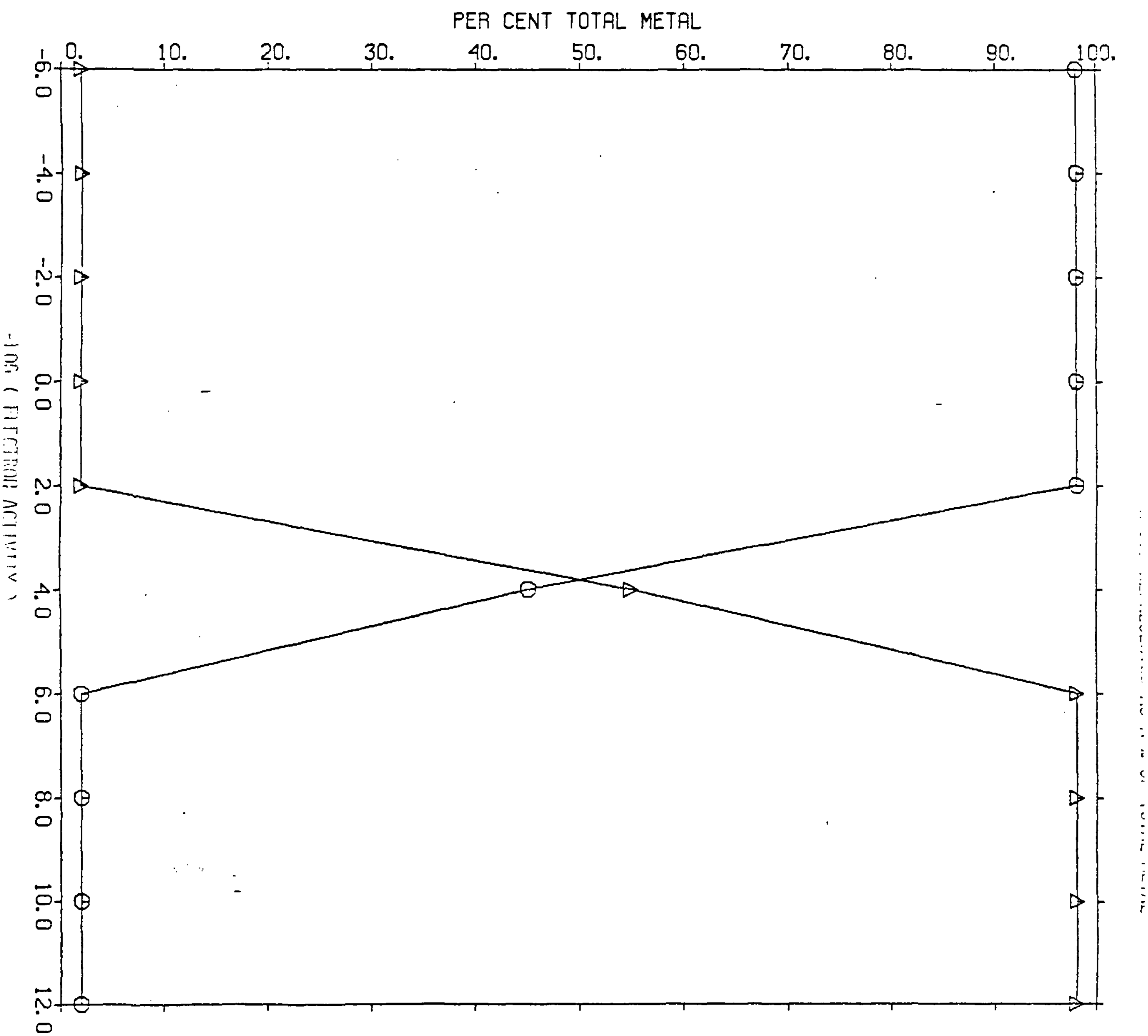
FIRST-ORDER KINETIC PLOT FOR CR(VI) AND CYSTEINE



CASE NUMBER 3 FIGURE 8

FIRST-ORDER KINETIC PLOT FOR HS^- AND CR(VI) KINETIC ANALYSIS NOT APPLICABLE




PER CENT TOTAL METAL
0. 10. 20. 30. 40. 50. 60. 70. 80. 90. 100.
-6.0 -4.0 -2.0 0.0 2.0 4.0 6.0 8.0 10.0 12.0
-LOG (ELECTRON ACTIVITY)
CRCI
CRCV

01425

1000493

USER NO REG = F004185
JOBCARD DATE = 1E0
RTN CARD SITE = FX

SAMPLE OUTPUT FOR A COMPUTER GENERATED MODEL FOR THE FATE OF TRACE METALS IN FLY ASH POND DISCHARGE

JOB	SITE	DATE	TIME
[illegible]	[illegible]	77/11/2	17.16.43.
COMPLETE		77/11/2	17.20.04.
PRINTED	F4	77/11/2	17.26.43.

CARDS READ

SECTORS RELEASED 0204.

ADSORPTION DATA

XKTE = .253
XEPPT= 14 .10000
EW= 1.35E00
EPSOH = 78.50000
ZEQ= 1.0000

SURF CF RZC EPSIL
9 3.50 6.15

INPUT DATA FOR VERIFICATION

MET LIG SOLIDS COMPLEXES

MET	LIG			SOLIDS		COMPLEXES					
7	1	[illegible]	1 1 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0
7	2		0 0 0	0 0 0 0	0 0 0	183 1 1 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0
7	3		0 0 0	0 0 0	0 0 0	71 1 1 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0
7	7		0 0 0	0 0 0 0	0 0 0 0	129 1 1 0	209 1 2 0	359 1 4 0	0 0 0 0	0 0 0 0	0 0 0 0
7	8	1773	1 1 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0
7	9	3466	3 2 0	0 0 0 0	0 0 0 0	1538 1 1 1	2171 1 1 2	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0
7	14		0 0 0	0 0 0 0	0 0 0	3567 1 6 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0
7	9		0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0
7	99	-13[illegible]	1 0-2	0 0 0 0	0 0 0 0	-231 1 0-1	-2073 1 0-2	-3206 1 0-3	-4630 1 0-4	-303 2 0-2	0 0 0 0
6	1		0 0 0	0 1 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0
6	2		0 0 0	0 0 0 0	0 0 0	345 1 1 0	467 1 2 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0
6	3		0 0 0	0 1 0 0	0 0 0 0	122 1 1 0	164 1 2 0	75 1 3 0	0 0 0 0	0 0 0 0	0 0 0 0
6	7		0 0 0	0 1 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0
6	8		0 0 0	0 0 0 0	0 0 0 1	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0
6	9	[illegible]	1 1 0	0 0 0 0	0 0 0 0	1990 1 1 1	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0
6	14		0 0 0	0 1 1 0	0 0 0 0	4332 1 6 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0
6	99		0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0

01426

100492

9	[illegible]		0 0 0	0	0 0 0	0	0 0 0	193	1 1 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
9	[illegible]		0 0 0	0	0 0 0	0	0 0 0	141	1 1 0	192	1 2 0	162	1 3 0	121	1 4 0	[illegible]	1 1-1	0	0 0 0
9	7		0 0 0	0	0 0 0	0	0 0 0	409	1 1 0	759	1 2 0	1049	1 3 0	1259	1 4 0	0	0 0 0	0	0 0 0
9	8	[illegible]	1 1 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
9	9	[illegible]	3 2 0	0	0 0 0	0	0 0 0	1538	1 1 1	[illegible]	1 1 2	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
9	14		0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
9	9[illegible]		0 0 0	0	0 0 0	0	0 0 0	0	123 0	-11	123-1	-13	123-2	-6	123-3	9	123-4	-13	223-2
9	99	[illegible]	1 0 -2	0	0 0 0	0	0 0 0	[illegible]	1 0-1	[illegible]	1 0-2	-2686	1 0-3	[illegible]	1 0-4	-1033	2 0-2	0	0 0 0
19	1		0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
19	2		0 0 0	0	0 0 0	0	0 0 0	215	1 1 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
19	3		0 0 0	0	0 0 0	0	0 0 0	52	1 1 0	-45	1 2 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
19	7		0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
19	8		0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
19	9		0 0 0	0	0 0 0	0	0 0 0	[illegible]	1 1 1	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
19	14		0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
19	9[illegible]		0 0 0	0	0 0 0	0	0 0 0	0	121 0	-20	121-1	-31	121-2	-27	121-4	0	0 0 0	0	0 0 0
19	99	[illegible]	1 0 -3	0	0 0 0	0	0 0 0	-350	1 0-1	[illegible]	1 0-2	-2407	1 0-4	239	2 0**	47	1 0-7	90	1 0-8
12	1	[illegible]	1 1 0	0	0 0 0	0	0 0 0	493	1 1 0	1186	1 1 1	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
12	2		0 0 0	0	0 0 0	0	0 0 0	193	1 1 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
12	3		0 0 0	0	0 0 0	0	0 0 0	121	1 1 0	142	1 2 0	52	1 3 0	-720	1 1-1	101	1 4 0	0	0 0 0
12	7		0 0 0	0	0 0 0	0	0 0 0	219	1 1 0	449	1 2 0	699	1 3 0	899	1 4 0	0	0 0 0	0	0 0 0
12	8	[illegible]	1 1 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
12	9	[illegible]	3 2 0	0	0 0 0	0	0 0 0	1458	1 1 1	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
12	14		0 0 0	0	0 0 0	0	0 0 0	1701	1 4 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
12	9[illegible]		0 0 0	0	0 0 0	0	0 0 0	0	123 0	-11	123-1	-6	123-3	9	123-4	-13	123-2	6	223-1
12	99	[illegible]	1 0 -2	0	0 0 0	0	0 0 0	-911	1 0-1	-2836	1 0-3	-4100	1 0-4	-1693	1 0-2	-893	2 0-1	0	0 0 0
15	1	[illegible]	1 1 1	[illegible]	[illegible]	0	0 0 0	703	1 1 0	1043	1 2 0	1286	1 1 1	2481	1 2 2	0	0 0 0	0	0 0 0
15	2	[illegible]	1 1 0	0	0 0 0	0	0 0 0	233	1 1 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
15	3		0 0 0	0	0 0 0	0	0 0 0	151	1 1 0	232	1 2 0	252	1 3 0	181	1 4 0	-660	1 1-1	0	0 0 0
15	7		0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
15	8	[illegible]	1 1 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
15	9	[illegible]	1 1 1	[illegible]	[illegible]	[illegible]	[illegible]	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
15	14		0 0 0	0	0 0 0	0	0 0 0	[illegible]	1 4 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
15	9[illegible]		0 0 0	0	0 0 0	0	0 0 0	0	129 0	-11	129-1	-13	129-2	-6	129-3	6	229-1	-27	329-4
15	99	[illegible]	1 0 -2	0	0 0 0	0	0 0 0	-701	1 0-1	-1723	1 0-2	-2816	1 0-3	-623	2 0-1	-2617	3 0-4	-4378	6 0-8
11	1	[illegible]	1 1 0	0	0 0 0	0	0 0 0	593	1 1 0	1186	1 1 1	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
11	2		0 0 0	0	0 0 0	0	0 0 0	193	1 1 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
11	3		0 0 0	0	0 0 0	0	0 0 0	201	1 1 0	242	1 2 0	182	1 3 0	141	1 4 0	-690	1 1-1	0	0 0 0
11	7		0 0 0	0	0 0 0	0	0 0 0	249	1 1 0	449	1 2 0	599	1 3 0	679	1 4 0	649	1 5 0	479	1 6 0
11	8	[illegible]	1 1 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
11	9		0 0 0	0	0 0 0	0	0 0 0	335	1 1 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
11	14		0 0 0	0	0 0 0	0	0 0 0	591	1 1 0	1112	1 2 0	1582	1 3 0	1921	1 4 0	0	0 0 0	0	0 0 0
11	9[illegible]		0 0 0	0	0 0 0	0	0 0 0	0	126 0	-11	126-1	-13	126-2	-6	126-3	9	126-4	6	226-1
11	99	[illegible]	1 0 -2	0	0 0 0	0	0 0 0	[illegible]	1 0-1	-2053	1 0-2	-3336	1 0-3	-4740	1 0-4	-933	2 0-1	-3280	4 0-4
5[illegible]	1	47	0 1 2	0	0 0 0	0	0 0 0	[illegible]	0 1 1	1647	0 1 2	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
5[illegible]	2		0 0 0	0	0 0 0	0	0 0 0	184	0 1 1	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
5[illegible]	3		0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
5[illegible]	7		0 0 0	0	0 0 0	0	0 0 0	922	0 1 1	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
5[illegible]	8		0 0 0	0	0 0 0	0	0 0 0	1374	0 1 1	[illegible]	0 1 2	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
5[illegible]	[illegible]		0 0 0	0	0 0 0	0	0 0 0	1215	0 1 1	1019	0 1 2	2122	0 1 3	0	0 0 0	0	0 0 0	0	0 0 0
5[illegible]	14		0 0 0	0	0 0 0	0	0 0 0	923	0 1 1	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
5[illegible]	99		0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0
5[illegible]	99		0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0	0	0 0 0

RED[illegible] DAT[illegible]	[illegible]ED	[illegible]	LP[illegible]OX	[illegible]LE[illegible]	[illegible]IRED	RED[illegible]ST
	-1[illegible]	2	1	-1	6	1277
	1[illegible]	2	[illegible]	-[illegible]	8	1901
	[illegible]	4	[illegible]	6	-14	-132[illegible]
	[illegible]	4	[illegible]	[illegible]	-7	-67[illegible]
	[illegible]	4	[illegible]	[illegible]	-8	-7[illegible]

01428

1000491

THESE CALCULATIONS INVOLVE [illegible] METALS, [illegible] LIGANDS, [illegible] COMPLEXES AND 2[illegible] POSSIBLE SOLIDS.

[illegible] ADSORBING SURFACES ARE INCLUDED ([illegible] METALS, 1 LIGANDS).

IONIC STRENGTH= .1000000E-01

1[illegible] DIFFERENT CASES ARE TREATED

THE CONDITIONS FOR THE DIFFERENT CASES ARE

METAL	I MAT	GUESS	TOTCC 1	TOTCC 2	TOTCC 3	TOTCC 4	TOTCC 5	TOTCC 6	TOTCC 7	TOTCC 8	TOTCC 9	TOTCC10
FE	7	8.[illegible]	8.[illegible]	[illegible].100	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
FE	[illegible]	8.[illegible]	4.[illegible]	4.60	4.600	4.600	4.600	4.600	4.600	4.600	4.600	4.600
CU	9	8.[illegible]	5.[illegible]	5.[illegible]	5.800	5.800	5.800	5.800	5.800	5.800	5.800	5.800
CD	19	8.[illegible]	5.100	5.100	5.100	5.100	5.100	5.100	5.100	5.100	5.100	5.100
ZN	12	8.[illegible]	5.900	5.90[illegible]	5.900	5.900	5.900	5.900	5.900	5.900	5.900	5.900
PB	[illegible]	8.[illegible]	6.[illegible]	6.60[illegible]	6.600	6.600	6.600	6.600	6.600	6.600	6.600	6.600
CO	11	8.[illegible]	6.7[illegible]	6.70[illegible]	6.700	6.700	6.700	6.700	6.700	6.700	6.700	6.700
LIGAND	I MAT	GUESS	TOTCC 1	TOTCC 2	TOTCC 3	TOTCC 4	TOTCC 5	TOTCC 6	TOTCC 7	TOTCC 8	TOTCC 9	TOTCC10
CO3	1	8.[illegible]	2.600	2.60[illegible]	2.600	2.600	2.600	2.600	2.600	2.600	2.600	2.600
SO4	2	8.[illegible]	3.500	3.50[illegible]	3.500	3.500	3.500	3.500	3.500	3.500	3.500	3.500
CL	3	8.[illegible]	2.400	2.40[illegible]	2.400	2.400	2.400	2.400	2.400	2.400	2.400	2.400
NH3	7	8.[illegible]	3.100	3.10[illegible]	3.100	3.100	3.100	3.100	3.100	3.100	3.100	3.100
S	[illegible]	8.[illegible]	8.000	8.00[illegible]	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
PO4	9	8.[illegible]	3.[illegible]	3.900	3.900	3.900	3.900	3.900	3.900	3.900	3.910	3.900
CN	14	8.[illegible]	5.7[illegible]	5.700	5.700	5.700	5.700	5.700	5.700	5.700	5.700	5.700
ADS1	[illegible]	5.[illegible]	3.[illegible]	3.00[illegible]	3.[illegible]00	3.000	3.000	3.000	3.000	3.000	3.000	3.000
FIXED PH			9.500	9.50[illegible]	9.500	9.500	9.500	9.500	9.500	9.500	9.500	9.500

REDOX POTENTIAL	-6.000	-4.000	-2.000	0.000	2.000	4.000	6.000	8.000	10.000	12.000

01429

1000490

CASE NUMBER 1

ADSORPTION CONSTANTS

CONSTANTS FOR ADSORPTION ON SURFACE SITES

METAL	LOG K (AT 0)						GCOUL						GSOLV						GCHEM
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	
CU2+	[illegible]	[illegible]	[illegible]	-2786	[illegible]	-971	-11.4	-5.7	0.0	5.7	11.4	-11.4	17.9	4.5	0.0	4.5	17.9	17.9	-11.0
CR	[illegible]	-266	[illegible]	[illegible]	[illegible]	[illegible]	-17.3	-11.5	-5.6	5.8	*****	*****	41.3	18.4	4.6	4.6	*****	*****	-11.8
ZN	[illegible]	-514	[illegible]	[illegible]	[illegible]	[illegible]	-11.4	-5.7	5.7	11.4	0.0	-17.1	17.8	4.4	4.4	17.8	0.0	40.0	-11.0
PB	12	[illegible]	[illegible]	[illegible]	-1111	[illegible]	[illegible]	-5.5	0.0	5.5	-16.4	-10.9	15.7	3.9	0.0	3.9	35.2	15.7	-11.0
CD	[illegible]	[illegible]	[illegible]	-3422	[illegible]	[illegible]	-11.1	-5.6	0.0	5.6	11.1	-16.7	16.6	4.2	0.0	4.2	16.6	37.4	-11.0

NUMBER OF ITERATIONS= 1

SOLID [illegible] S 1 PRECIPITATES

NUMBER OF ITERATIONS= 1

SOLID [illegible] S 1 PRECIPITATES

NUMBER OF ITERATIONS= 15

SOLID [illegible] S 1 PRECIPITATES

NUMBER OF ITERATIONS= 2[illegible]

01430

1000489

NUMBER OF ITERATIONS= 22

IONIC STRENGTH= 1.0000000E-02

FIXED PH= 9.500 COMPUTED TOTH= .2378161E-02

PE= -6.00

	FREE CONC	LOG FREE CONC	TOT CONC	LOG TOT CONC	REMAINDER
FE2	1.6192954E-12	11.79067	0.	********	-7.5894152E-19
FE3	2.7499587E-31	30.56067	2.5128864E-05	4.59983	-7.5894152E-19
CU2+	5.8151778E-27	26.23544	1.5848932E-06	5.80000	0.
CR	9.3120599E-20	19.03095	7.9432823E-06	5.10000	-1.2955023E-14
ZN	2.9144920E-11	10.53544	1.2589254E-06	5.90000	0.
PB	1.4607066E-17	16.83544	2.5118864E-07	6.60000	0.
CD	1.8389207E-17	16.73544	1.9952623E-07	6.70000	0.
CO3-	4.6792735E-04	3.32982	2.5118864E-03	2.60000	1.8452227E-14
SO4	3.1292265E-04	3.50456	3.1623777E-04	3.49999	-9.7762904E-13
CL	3.9810717E-03	2.40000	3.9810717E-03	2.40000	3.8334154E-16
NH3	5.2093674E-04	3.28322	7.9432823E-04	3.10000	3.6429193E-17
S	2.0203983E-12	11.69456	3.3151033E-06	5.47950	-9.7762904E-13
PO4	2.8023922E-07	6.55247	1.2589254E-04	3.90000	1.6749055E-17
CN	1.2981127E-06	5.88669	1.9952623E-06	5.70000	3.7269450E-20
ADS1	9.9942186E-04	3.00025	1.0000000E-03	3.00000	2.0493158E-11

SOLID			MOLES PER LITER OF SOLUTION
CU2+	S	1	1.5848932E-06
ZN	S	1	1.2442884E-06
PB	S	1	2.5118847E-07
CD	S	1	1.9952623E-07

* *

CONCENTRATIONS OF COMPLEXES

FE2	SO4	13.47	1 1 0										
FE2	CL	13.48	1 1 0										
FE2	NH3	13.78	1 1 0	16.27	1 2 0	21.33	1 4 0						
FE2	PO4	12.46	1 1 1	15.63	1 1 2								
FE2	CN	11.44	1 6 0										
FE2	OH	4.60	1 0-1	13.52	1 0-2	15.35	1 0-3	20.09	1 0-4	7.61	2 0-2		
FE3	SO4	3[illegible].62	1 1 0	32.40	1 2 0								
FE3	CL	31.74	1 1 0	33.72	1 2 0	37.01	1 3 0						
FE3	PO4	26.71	1 1 1										
FE3	CN	22.56	1 6 0										
FE3	OH	23.46	1 0-1	17.57	1 0-2	14.43	1 0-4	45.06	2 0-2	100.00	3 0-4		
CU2+	CO3-	23.24	1 1 0	23.37	1 2 0	26.91	1 1 1	23.70	1 1-2				
CU2+	SO4	27.81	1 1 0										
CU2+	CL	27.23	1 1 0	29.12	1 2 0	31.82	1 3 0	34.63	1 4 0	24.24	1 1-1		
CU2+	NH3	25.43	1 1 0	25.21	1 2 0	25.60	1 3 0	26.78	1 4 0				
CU2+	PO4	26.91	1 1 1	31.08	1 1 2								
CU2+	ADS1	28.63	123 0	23.78	123-1	20.64	123-2	28.60	123-3	40.35	123-4	46.18	223-2
CU2+	OH	24.75	1 0-1	21.07	1 0-2	24.60	1 0-3	28.04	1 0-4	43.80	2 0-2		
CR	SO4	20.39	1 1 0										

01431

1121

CR	ADS1	20.67	121 0	15.19	121-1	7.02	121-2	8.79	121-4				
CR	OH	13.03	1 0-1	9.14	1 0-2	5.10	1 0-4	100.00	2 0**	38.45	1 0-7	35.02	1 0-8
ZN	CO3-	8.94	1 1 0	11.51	1 1 1								
ZN	SO4	12.11	1 1 0										
ZN	CL	11.73	1 1 0	13.92	1 2 0	17.22	1 3 0	10.64	1 1-1	19.13	1 4 0		
ZN	NH3	11.63	1 1 0	12.61	1 2 0	13.40	1 3 0	14.68	1 4 0				
ZN	PO4	12.01	1 1 1										
ZN	CN	17.07	1 4 0										
ZN	ADS1	12.89	123 0	9.18	123-1	14.38	123-3	25.80	123-4	8.04	123-2	30.02	223-1
ZN	OH	1 .15	1 0-1	10.40	1 0-3	13.54	1 0-4	8.47	1 0-2	20.50	2 0-1		
PB	CO3-	13.14	1 1 0	13.07	1 2 0	16.81	1 1 1	17.69	1 2 2				
PB	SO4	18.01	1 1 0										
PB	CL	17.73	1 1 0	19.32	1 2 0	21.52	1 3 0	24.63	1 4 0	16.54	1 1-1		
PB	CN	29.97	1 4 0										
PB	ADS1	18.59	129 0	14.15	129-1	14.74	129-2	20.25	129-3	38.28	229-1	40.42	329-4
PB	OH	15.15	1 0-1	15.07	1 0-2	16.50	1 0-3	30.40	2 0-1	38.68	3 0-4	100.00	6 0-8
CD	CO3-	15.04	1 1 0	17.71	1 1 1								
CD	SO4	18.31	1 1 0										
CD	CL	17.13	1 1 0	19.12	1 2 0	22.12	1 3 0	24.93	1 4 0	16.54	1 1-1		
CD	NH3	17.53	1 1 0	18.81	1 2 0	20.60	1 3 0	23.08	1 4 0	26.66	1 5 0	31.64	1 6 0
CD	PO4	19.94	1 1 0										
CD	CN	16.71	1 1 0	17.39	1 2 0	18.58	1 3 0	21.07	1 4 0				
CD	ADS1	16.77	126 0	16.36	126-1	17.90	126-2	25.46	126-3	37.85	126-4	41.94	226-1
CD	OH	17.35	1 -1	18.27	1 0-2	21.60	1 0-3	26.14	1 0-4	33.30	2 0-1	100.00	4 0-4
H	CO3-	2.69	0 1 1	5.86	0 1 2								
H	SO4	11.16	0 1 1										
H	NH3	3.56	0 1 1										
H	S	7.45	0 1 1	10.02	0 1 2								
H	PO4	3.90	0 1 1	6.36	0 1 2	13.83	0 1 3						
H	CN	6.16	0 1 1										

* *

	FREE MET	CO3-	SO4	CL	NH3	S	PO4	CN	ADS1	OH
FREE LIG		3.33	3.50	2.40	3.28	11.69	6.55	5.89	3.00	4.43
FE2	11.79	*****	13.47	13.48	13.78	*****	12.46	11.44	*****	4.60
FE3	30.56	*****	30.61	31.74	*****	*****	26.71	22.56	*****	14.43
CU2+	26.74	22.92	27.81	24.23	24.90	*****	26.91	*****	20.64	21.07
CR	19.03	*****	20.39	20.91	*****	*****	14.38	*****	7.78	5.10
ZN	10.54	8.93	12.11	10.60	11.58	*****	12.01	17.07	8.01	8.45
PB	16.84	12.80	18.01	16.51	*****	*****	*****	29.97	14.05	14.79
CD	16.74	15.03	18.31	16.44	17.51	*****	19.94	16.62	16.34	17.30
HYDROGEN	9.50	2.69	11.16	*****	3.56	7.45	3.90	6.16	*****	*****

1000488

PRIMARY DISTRIBUTION OF METALS AND LIGANDS

```
FE2
     BOUND WITH OH  /  100.0 PERCENT
FE3
CU2+
     IN SOLID FORM WITH S   /  100.0 PERCENT
CR
     BOUND WITH OH  /   99.8 PERCENT
ZN
     IN SOLID FORM WITH S   /   9[illegible].8 PERCENT
     BOUND WITH ADSI/          .8 PERCENT
PB
     IN SOLID FORM WITH S   /  100.0 PERCENT
CD
     IN SOLID FORM WITH S   /  100.0 PERCENT
CO3-
     AS A FREE LIGAND/   18.6 PERCENT
     BOUND WITH H   /   81.4 PERCENT
SO4
     AS A FREE LIGAND/   97.9 PERCENT
CL
     AS A FREE LIGAND/  100.0 PERCENT
NH3
     AS A FREE LIGAND/   65.6 PERCENT
     BOUND WITH H   /   34.4 PERCENT
S
PO4
     BOUND WITH H   /   99.8 PERCENT
CN
     AS A FREE LIGAND/   65.1 PERCENT
     BOUND WITH H   /   34.9 PERCENT
ADSI
     AS A FREE LIGAND/   99.9 PERCENT
```

* *

* *

CASE NUMBER 2

* *

01433

132140

ADSORPTION CONSTANTS

CONSTANTS FOR ADSORPTION ON SURFACE ADS1

METAL	LOGK (X100) 1	2	3	4	5	6	BCOUL 1	2	3	4	5	6	GSOLV 1	2	3	4	5	6	GCHEM
CU2+	61	-404	-1041	-2786	-4911	-971	-11.4	-5.7	0.0	5.7	11.4	-11.4	17.9	4.5	0.0	4.5	17.9	17.9	-11.0
CR	-664	-266	-479	-2476	50000	50000	-17.3	-11.5	-5.8	5.8	*****	*****	41.3	18.4	4.6	4.6	*****	*****	-11.8
ZN	65	-514	-934	-5026	-135	-1545	-11.4	-5.7	5.7	11.4	0.0	-17.1	17.8	4.4	4.4	17.8	0.0	40.0	-11.0
PB	125	-391	-139	-2891	-1111	-2491	-10.9	-5.5	0.0	5.5	-16.4	-10.9	15.7	3.9	0.0	3.9	35.2	15.7	-11.0
CD	97	-612	-1716	-3422	-5611	-1497	-11.1	-5.6	0.0	5.6	11.1	-16.7	16.6	4.2	0.0	4.2	16.6	37.4	-11.0

1000486

NUMBER OF ITERATIONS=158

IONIC STRENGTH= 1.0000000E-02

FIXED PH= 9.500   COMPUTED TOTH= .2263601E-02

PE= 12.00

	FREE CONC	LOG FREE CONC	TOT CONC	LOG TOT CONC	REMAINDER
FE2	6.3095734E-25	24.20000	0.	********	-9.3865338E-20
FE3	1.0715193E-25	24.97000	2.5128864E-05	4.59983	-9.3865338E-20
CU2+	2.9882990E-12	11.52458	1.5848932E-06	5.80000	-1.5935310E-21
CR	7.7595887E-44	43.11016	7.9432823E-06	5.10000	5.9631119E-19
ZN	2.5856704E-09	8.58743	1.2589254E-06	5.90000	2.1246117E-20
PB	2.1645445E-11	10.66463	2.5118864E-07	6.60000	1.4914707E-20
CD	7.9421474E-11	10.10006	1.9952623E-07	6.70000	0.
CO3-	4.678 198E-04	3.32994	2.5118864E-03	2.60000	-7.8545365E-18
SO4	3.1623769E-04	3.49999	3.1623777E-04	3.49999	-8.2410983E-19
CL	3.9811690E-03	2.40000	3.9810717E-03	2.40000	-1.0013926E-17
NH3	5.2093648E-04	3.28322	7.9432823E-04	3.10000	8.6736174E-18
S	2.0419020-156	********	3.5579996-152	********	-8.2410983E-19
PO4	2.8021903E-07	6.55247	1.2589254E-04	3.90000	-1.4265159E-18
CN	1.2981472E-06	5.88671	1.9952623E-06	5.70000	-1.0164395E-20
ADS1	9.5425080E-04	3.02034	1.0000000E-03	3.00000	-9.1535015E-20

SOLID			MOLES PER LITER OF SOLUTION
FE3	OH	1	2.5127418E-05
CD	CO3-	1	1.9497083E-07

* *

CONCENTRATIONS OF COMPLEXES

FE2	SO4	25.87	1 1 0				
FE2	CL	25.89	1 1 0				
FE2	NH3	26.19	1 1 0	28.58	1 2 0	33.74	1 4 0

01434

(32141

FE2	OH	17.01	1 0-1	25.93	1 0-2	27.76	1 0-3	32.50	1 0-4	32.43	2 0-2		
FE3	SO4	25.02	1 1 0	27.36	1 2 0								
FE3	CL	26.15	1 1 0	29.13	1 2 0	31.42	1 3 0						
FE3	PO4	21.12	1 1 1										
FE3	CN	16.97	1 6 0										
FE3	OH	17.87	1 0-1	11.98	1 0-2	8.84	1 0-4	33.88	2 0-2	43.20	3 0-4		
CU2+	CO3-	8.52	1 1 0	8.65	1 2 0	12.19	1 1 1	8.98	1 1-2				
CU2+	SO4	13.09	1 1 0										
CU2+	CL	12.51	1 1 0	14.40	1 2 0	17.10	1 3 0	19.91	1 4 0	9.52	1 1-1		
CU2+	NH3	10.72	1 1 0	10.50	1 2 0	10.88	1 3 0	12.07	1 4 0				
CU2+	PO4	12.20	1 1 1	15.37	1 1 2								
CU2+	ADS1	13.93	123 0	9.08	123-1	5.94	123-2	13.90	123-3	25.65	123-4	16.78	223-2
CU2+	OH	10.03	1 0-1	6.35	1 0-2	9.88	1 0-3	13.32	1 0-4	14.38	2 0-2		
CR	SO4	44.46	1 1 0										
CR	CL	44.99	1 1 0	48.36	1 2 0								
CR	PO4	34.46	1 1 1										
CR	ADS1	100.00	121 0	39.29	121-1	31.92	121-2	32.89	121-4				
CR	OH	37.11	1 0-1	34.22	1 0-2	29.18	1 0-4	14.02	2 0**	8.53	1 0-7	5.10	1 0-8
ZN	CO3-	6.99	1 1 0	9.56	1 1 1								
ZN	SO4	1[illegible].16	1 1 0										
ZN	CL	9.78	1 1 0	11.97	1 2 0	15.27	1 3 0	8.69	1 1-1	17.18	1 4 0		
ZN	NH3	9.68	1 1 0	10.66	1 2 0	11.45	1 3 0	12.73	1 4 0				
ZN	PO4	10.06	1 1 1										
ZN	CN	15.12	1 4 0										
ZN	ADS1	10.96	123 0	7.25	123-1	12.45	123-3	23.87	123-4	6.11	123-2	26.15	223-1
ZN	OH	9.20	1 0-1	8.45	1 0-3	11.59	1 0-4	6.52	1 0-2	16.60	2 0-1		
PB	CO3-	6.96	1 1 0	6.89	1 2 0	10.63	1 1 1	11.51	1 2 2				
PB	SO4	11.83	1 1 0										
PB	CL	11.55	1 1 0	13.14	1 2 0	15.34	1 3 0	18.45	1 4 0	10.36	1 1-1		
PB	CN	23.80	1 4 0										
PB	ADS1	12.43	129 0	7.99	129-1	8.58	129-2	14.09	129-3	25.96	229-1	21.92	329-4
PB	OH	8.97	1 0-1	8.89	1 0-2	10.32	1 0-3	18.06	2 0-1	20.16	3 0-4	31.77	6 0-8
CD	CO3-	8.40	1 1 0	11.07	1 1 1								
CD	SO4	11.67	1 1 0										
CD	CL	1[illegible].49	1 1 0	12.48	1 2 0	15.48	1 3 0	18.29	1 4 0	9.90	1 1-1		
CD	NH3	1[illegible].89	1 1 0	12.18	1 2 0	13.96	1 3 0	16.44	1 4 0	20.03	1 5 0	25.01	1 6 0
CD	PO4	13.30	1 1 [illegible]										
CD	CN	15.08	1 1 0	10.75	1 2 0	11.94	1 3 0	14.44	1 4 0				
CD	ADS1	12.15	126 0	9.74	126-1	11.28	126-2	18.84	126-3	31.23	126-4	28.69	226-1
CD	OH	1[illegible].71	1 0-1	11.63	1 0-2	14.96	1 0-3	19.50	1 0-4	20.03	2 0-1	35.20	4 0-4
H	CO3-	2.69	0 1 1	5.86	0 1 2								
H	SO4	11.16	0 1 1										
H	NH3	3.56	0 1 1										
H	S	100.00	0 1 1	100.00	0 1 2								
H	PO4	3.90	0 1 1	6.36	0 1 2	13.83	0 1 3						
H	CN	6.16	0 1 1										

* *

	FREE MET	CO3-	SO4	CL	NH3	S	PO4	CN	ADS1	OH
FREE LIG		3.31	3.50	2.40	3.28	*****	6.55	5.89	3.02	4.43
FE2	24.20	*****	25.87	25.89	26.19	*****	24.87	23.85	*****	17.01
FE3	24.97	*****	25.02	26.15	*****	*****	21.12	16.97	*****	8.84
CU2+	11.52	8.20	13.09	9.52	10.19	*****	12.20	*****	5.94	6.35

1000485

CR	43.11	*****	44.46	44.99	*****	*****	38.46	*****	31.88	5.10
ZN	8.59	6.99	10.16	8.65	9.63	*****	10.06	15.12	6.08	6.50
PB	10.66	6.63	11.83	10.34	*****	*****	*****	23.80	7.90	8.62
CO	10.10	8.40	11.67	9.80	10.87	*****	13.30	9.99	9.73	10.66
HYDROGEN	9.50	2.69	11.16	*****	3.56	*****	3.90	6.16	*****	*****

* *

PRIMARY DISTRIBUTION OF METALS AND LIGANDS

FE2

FE3
    IN SOLID FORM WITH OH / 100.0 PERCENT

CU2+
    BOUND WITH ADS1/ 71.7 PERCENT
    BOUND WITH OH / 27.9 PERCENT

CR
    BOUND WITH OH / 100.0 PERCENT

ZN
    BOUND WITH CO3-/ 8.2 PERCENT
    BOUND WITH ADS1/ 65.5 PERCENT
    BOUND WITH OH / 24.9 PERCENT

PB
    BOUND WITH CO3-/ 94.0 PERCENT
    BOUND WITH ADS1/ 5.1 PERCENT
    BOUND WITH OH / .9 PERCENT

CD
    BOUND WITH CO3-/ 2.0 PERCENT
    IN SOLID FORM WITH CO3-/ 97.7 PERCENT

CO3-
    AS A FREE LIGAND/ 18.6 PERCENT
    BOUND WITH H / 81.3 PERCENT

SO4
    AS A FREE LIGAND/ 100.0 PERCENT

CL
    AS A FREE LIGAND/ 100.0 PERCENT

NH3
    AS A FREE LIGAND/ 65.6 PERCENT
    BOUND WITH H / 34.4 PERCENT

S

PO4
    BOUND WITH H / 99.8 PERCENT

```
     AS A FREE LIGAND/    65.1 PERCENT
     BOUND WITH H    /    34.9 PERCENT

ADS1
     AS A FREE LIGAND/    95.4 PERCENT
     BOUND WITH CU2+/      2.6 PERCENT
     BOUND WITH ZN   /     1.9 PERCENT
```

* *

POTENTIAL TRANSFORMATIONS OF CHROMIUM IN NATURAL WATERS

DAVID C. SCHROEDER* and G. FRED LEE**

Institute for Environmental Sciences, University of Texas-Dallas, Richardson, Tex. 75080, U.S.A.

(Received 13 June, 1974; in revised form 29 October, 1974)

Abstract. A study has been conducted on the transformation of Cr(III) and Cr(VI) in simulated natural water conditions. It has been found that these forms are readily interconvertible under natural water conditions. The results of this study indicate that Cr(VI) is reduced by Fe(II), dissolved sulfides, and certain organic compounds with sulfhydryl groups, while Cr(III) is oxidized by a large excess of MnO_2 and at a slow rate by O_2 under conditions approximating those in natural waters. Based on the results of these studies, water quality standards for Cr should be based on total Cr rather than on Cr(VI), as has been frequently done in the past.

1. Introduction

A frequently recommended limit for Cr in natural waters of 0.05 mg l^{-1} of Cr(VI) is based on toxicity to aquatic life and on possible harmful effects on man when present in drinking water (FWPCA, 1968; McKee and Wolf, 1963; USPHS, 1962). Little attention has been given to Cr(III) either in toxicity studies or in the establishment of standards, although McKee and Wolf (1963) accumulated evidence to conclude that Cr(III) is also hazardous to aquatic life.

The objectives of this study are to consider the possibilities for and evidence of reduction of Cr(VI) and oxidation of Cr(III) in natural waters. Such reactions, if they occur, will have an effect on the distribution of Cr in these waters, since Cr(III) is known to be sorbed to a much greater extent by naturally occurring solids than is Cr(VI) (Canter and Gloyna, 1967; Krauskopf, 1956; Chuecas and Riley, 1966) and is also restricted in solubility in the pH range of natural waters (Pourbaix, 1966; Sillen and Martell, 1964). When both direction and rate of these reactions are considered, if Cr(VI) is favored, then the available evidence indicates that Cr will accumulate as soluble forms in the water. If Cr(III) is favored, then the accumulation will likely occur in the sediments. If Cr(III) and Cr(VI) are interconvertible in natural waters, then water quality standards for Cr should be based on total Cr and not Cr(VI) as has frequently been done in the past.

At pH 6.5 to 8.5, the overall oxidation reaction is (Latimer, 1952; Pourbaix, 1966; Sillen and Martell, 1964)

$$2Cr(OH)_2^+ + 1.5O_2 + H_2O \rightarrow 2CrO_4^{=} + 6H^+ . \qquad (1)$$

* Graduate student, University of Wisconsin.

** Director, Institute for Environmental Sciences, University of Texas, Dallas

Given the standard free energy change for this reaction (Latimer, 1952) as +12.7 kcal $mole^{-1}$, at pH = 7.0 and P_{O_2} = 0.21 atm, at equilibrium,

$$\frac{\{CrO_4^{=}\}}{\{Cr(OH)_2^{+}\}} = 7 \times 10^{15}$$

indicating that under oxygenated natural water conditions Cr(VI) is the thermodynamically stable species. It is possible, however, that Cr(III) could be kinetically stable *in natural water systems. The only previous study concerned with this reaction was* that of Canter and Gloyna (1967) who found evidence of appreciable oxidation of ^{51}Cr(III) in five days at pH 8 to 10; however, they found that ^{51}Cr(III) is sorbed to a much greater extent by glassware than is ^{51}Cr(VI). These investigators used analytical procedures which measure soluble species only. When the sorption is considered, it is difficult to show that any oxidation occurred, since the results are reported as fractions of total activity rather than as actual concentrations.

2. Materials and Methods

2.1. Measurement of Cr(VI) and Total Cr

Cr(VI) was measured by *the diphenylcarbazide method* and total Cr by the permanganate-azide method, both of which are described in Standard Methods (APHA *et al.*, 1971). The diphenylcarbazide method was evaluated and found to be specific for Cr(VI). Beer's Law was obeyed at concentrations up to 250 $\mu g\ l^{-1}$ and the detection limit was found to be 1 to 2 $\mu g\ l^{-1}$ with the apparatus used in this study.

The permanganate-azide method was also evaluated and found to be only marginally satisfactory with an average relative error of 21% and a relative standard deviation of 23% in a series of 22 determinations.

3. Results

3.1. Oxidation of Cr(III) by O_2

The rate of formation of Cr(VI) was determined in buffered solutions containing 100 to 125 $\mu g\ l^{-1}$ Cr(III) and DO. As a basis for comparison, a reference solution was used which contained 100 $\mu g\ l^{-1}$ Cr(III), 10^{-2} M $KHCO_3$ buffer, and glass-distilled water maintained at room temperature (22 to 26°C). This reference solution had an initial pH of 8.6.

To determine the effect of pH, the HCO_3^- buffer was replaced with $H_2PO_4^-$-$HPO_4^=$ buffer (pH 5.9) and with $CO_3^=$ (pH 9.9). To determine the effect of temperature, the reference solution was placed in water baths at 35°C and 45°C.

Figure 1 depicts the effect of temperature on the rate of oxidation of Cr(III) by DO in $KHCO_3$ buffer. At room temperature (22 to 26°C), the rate was slow with about 3% of the added Cr(III) oxidizing in 30 days. At 35°C, the same extent of oxidation occurred in 10 to 11 days, and, at 45°C, in less than 3 days. This temperature effect

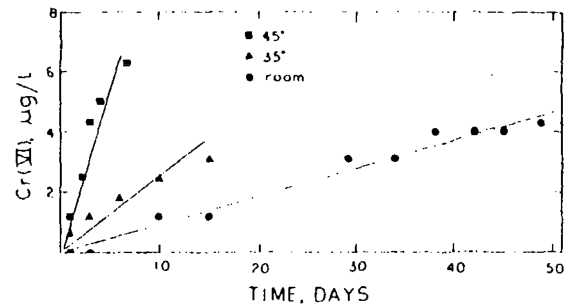


Fig. 1. Effect of temperature on the rate of oxidation of Cr(III) by O_2. Initial Cr(III) μg l^{-1}. Room temperature 22–26°C.

indicates a high activation energy based on the rates at room temperature and 45°C, E_a = 22 kcal $mole^{-1}$. In each case, approximately 20 to 25% of the Cr(III) was sorbed by glassware during the duration of the experiments and thus the true rate of oxidation was slightly higher than the apparent rate. Nevertheless, it appears that the rate of this reaction is sufficiently slow in natural waters that Cr(III) may be involved in other reactions, particularly sorption, before it can be oxidized by O_2.

In order to determine whether the materials in natural waters might influence the rate of oxidation of Cr(III) by DO, the rate was also measured in Lake Mendota, Wisconsin water, one sample of which was filtered through a 0.22 μ pore size filter, while another sample was left unfiltered except that aliquots were filtered just prior to CR(VI) measurement. Table I indicates that there was no evidence of such a catalyst in Lake Mendota water, since the rate in unfiltered lake water was essentially the same

TABLE I

Rate of oxidation of Cr(III) in Lake Mendota water, pH 8.1–8.7, room temperature, initial Cr(III) 125 $\mu g\ l^{-1}$

Time, days	Cr(VI), $\mu g\ l^{-1}$ [a]	Cr(VI), $\mu g\ l^{-1}$ [b]
0	< 1	1
1	< 1	< 1
4	< 1	1.3
5	1.9	5.0
7	2.5	3.0
11	1.1	3.8

[a] Unfiltered.
[b] Filtered.

as the rate in $KHCO_3$ buffer. The slightly higher apparent rate in filtered lake water can be attributed to the formation of turbidity in the sample, since aliquots from this sample were not filtered immediately prior to Cr(VI) measurement.

To determine the effect of sorption of Cr(III) on the rate of oxidation, to the reference solution was added (a) sand, 50 g l^{-1} (b) bentonite, 10 g l^{-1} (c) MnO_2, 0.10 g l^{-1}, and (d) $Fe(OH)_3$, 0.2 g l^{-1}. These mixtures were stirred thoroughly once each day and allowed to settle overnight before aliquots were taken and filtered through medium-porosity glass fiber before Cr(VI) analysis.

TABLE II

Effect of solids in sorbing Cr(III) and on rate of oxidation of Cr(III) in $KHCO_3$ buffer. All figures are percentages of the original Cr(III)

	Sand	Bentonite	MnO_2	$Fe(OH)_3$
Sorbed in 1 day	46	93	11	89
Sorbed in 7 days	90	95	0	99
Oxidized in 1 day	1	2	89	1
Oxidized in 3 days	0	-	91	1
Oxidized in 7 days	2	-	100	-
Oxidized in 8 days	-	1		0

TABLE III

Rate of oxidation of Cr(III) by O_2 in three different buffers. Figures are percentages of the original Cr(III)

	pH range 5.9	8.3-8.9	9.5-9.9
Sorbed in 1 day	15	40	14
Sorbed in 7 days	22	21	21
Sorbed in 14 days	22	-	
Oxidized in 1 day	1	1	1
Oxidized in 7 days	1	2	1
Oxidized in 14 days	1	1	1

Table II indicates that the naturally occurring solids studied all sorbed Cr(III) but that oxidation could only be detected with MnO_2. In the case of sand, bentonite, and $Fe(OH)_3$, there is no evidence to indicate that sorption of Cr(III) increases the rate of oxidation. MnO_2 appears to be a special case which will be discussed later.

Table III indicates that pH had no apparent effect on the rate of oxidation of Cr(III) by DO over the range of pH 5.9 to 9.9. Although there may well be a pH effect on this rate, the effect does not appear to be significant. In all cases, less than 2% of the added Cr(III) was oxidized in two weeks.

3.2. Oxidation of Cr(III) by MnO_2.

The rate of oxidation of Cr(III) in the presence of MnO_2 was determined by adding different amounts (25, 100, and 250 mg l^{-1}) of MnO_2 to reference solutions, stirring to keep the MnO_2 in uniform suspension, and filtering aliquots through medium-porosity glass fiber filters. The rate was also measured with Cr(III) and MnO_2 added to both filtered and unfiltered Lake Mendota water.

Figure 2 indicates that the rate of oxidation of Cr(III) in the presence of MnO_2 depends on the quantity of MnO_2, even when that quantity represents several hundred times the quantity required to oxidize all of the Cr(III) present. At 25 mg l^{-1} MnO_2, a weight ratio of MnO_2:Cr of 200:1, half of the added Cr(III) was oxidized in 42 min, but, at 250 mg l^{-1} MnO_2, only 3 min were required.

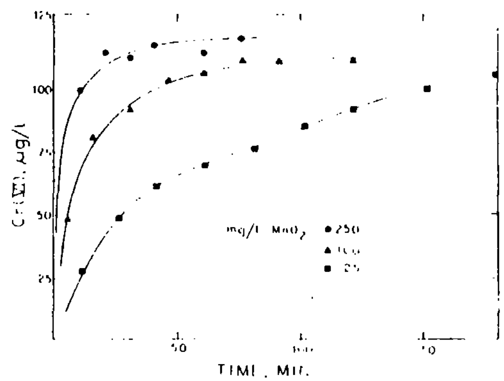


Fig. 2. Oxidation of Cr(III) by different amounts of MnO_2. Initial Cr(III) 125 μg l^{-1}.

Figure 3 indicates that the reaction was strongly inhibited in Lake Mendota water. In filtered lake water, it is possible that other cations such as Ca^{++} and Mg^{++} occupied sorption sites on the MnO_2 particles such that the reaction ceased with 65% of the Cr(III) oxidized. In unfiltered lake water, even more inhibition was noted, probably because of sorption of some of the Cr(III) by other solids.

These results suggest that oxidation of Cr(III) by MnO_2 requires sorption of the Cr(III) onto sorption sites which are few in number in relation to the total surface area. The scarcity of these sites and the marked inhibition in Lake Mendota water imply that MnO_2 is not likely to have a significant effect on the distribution of Cr forms in natural waters.

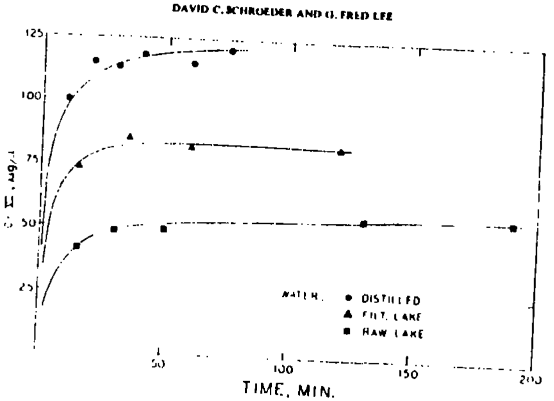


Fig. 3. Oxidation of Cr(III) by MnO_2 in buffered, distilled and in filtered and unfiltered Lake Mendota water. Initial Cr(III) 125 $\mu g\ l^{-1}$, MnO_2 250 $mg\ l^{-1}$.

3.3. Reduction of Cr(VI)

The rate of sorption of Cr(VI) was determined in buffered solutions to which selected reducing agents were added. To attempt to correct for sorption of Cr(VI) by glassware, no reducing agent was added to one solution. The reference buffer was 10^{-2} M $KHCO_3$. All solutions initially contained 100 $\mu g\ l^{-1}$ Cr(VI). Table IV indicates that the loss of Cr(VI) from the control sample proceeded at a rate of about 1 $\mu g\ l^{-1}$ week, a rate which is negligible in experiments lasting less than one day. The marked difference in rate and extent of sorption between Cr(III) and Cr(VI) is apparent.

TABLE IV

Loss of Cr(VI) from control sample

Time, days	Cr(VI), $\mu g\ l^{-1}$ *	Time, days	Cr(VI), $\mu g\ l^{-1}$ *
0	100	14	99
1	99	18	99
6	99	21	98
10	99	26	98

* In solution.

3.4. Reduction of Cr(VI) by Fe(II)

The effect of Fe(II) on Cr(VI) was determined by adding to the reference solution appropriate volumes of a $Fe(NH_4)_2(SO_4)_2$ stock solution prepared in dilute H_2SO_4.

In an additional reference solution, the pH was raised with 1N NaOH before Fe(II) was added. The initial reaction conditions were as follows: (a) 0.40 $mg\ l^{-1}$ Fe(II), pH 7.5 (b) 1.20 $mg\ l^{-1}$ Fe(II), pH 7.1, and (c) 0.40 $mg\ l^{-1}$ Fe(II), pH 9.1.

Figure 4 indicates that Fe(II) will reduce Cr(VI) in the pH range of interest but that the extent of this reduction will depend on pH and Fe(II) concentration as well as

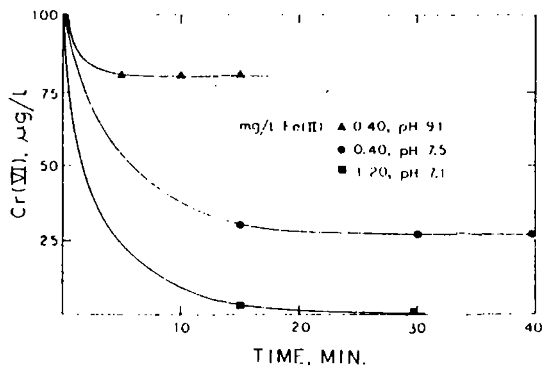


Fig. 4. Reduction of Cr(VI) by Fe(II).

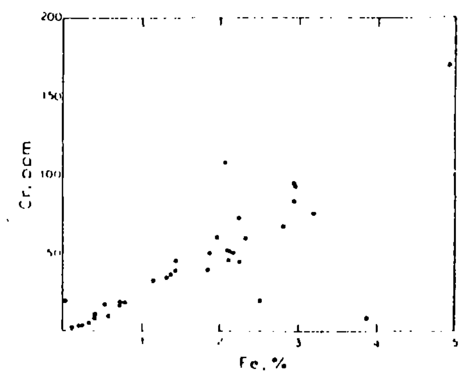


Fig. 5. The correlation between Cr and Fe content of Lake Michigan sediments using data from Copeland and Ayers (1972).

other factors. Fe(II) is, of course, also oxidized by O_2 in this pH range. At 0.40 mg l^{-1} Fe(II) and an initial pH of 7.5, approximately half of the original Fe(II) was oxidized by Cr(VI) and half by O_2, with 73% of the Cr(VI) being reduced. At an initial pH of 9.1, the Fe(II) O_2 reaction was favored and only 20% of the Cr(VI) was reduced. At pH 6.5 to 8.5, the overall reaction between Cr(VI) and Fe(II) is

$$3Fe^{++} + CrO_4^{=} + 7H_2O \rightarrow 3Fe(OH)_3 + Cr(OH)_2^{+} + 3H^{+} . \qquad (2)$$

As previously noted, Cr(III) is sorbed very effectively by $Fe(OH)_3$. The result of the occurrence of reaction (2) in a natural water is likely to lead to the accumulation of Fe and Cr in the sediments and quite possibly a correlation between the two such as that seen in Figure 5 and Table V.

TABLE V

Correlation coefficients for Cr content of southern Lake Michigan sediments with other parameters, after Shimp *et al.* (1971)

Sediment interval	With organic carbon	With < 2 μm clay	With water depth	With Fe_2O_3	With MnO_2
Top*	0.80	0.50	0.44	0.78	0.49
1 7 cm	0.72	0.49	0.20	0.76	0.47
4 12 cm	0.87	0.39	0.29	0.57	0.20
8 20 cm	0.94	0.79	0.66	0.79	0.42

* Variable, 2 4 cm.

Table V and Figure 5 are based on Shimp *et al.* (1971) and show a strong correlation between the Fe and Cr content of the sediments in Lake Michigan.

3.5. Reduction of Cr(VI) by Sulfides

To determine the effect of dissolved sulfides on Cr(VI), a reference solution was made 10^{-3} M in Na_2S. The resultant pH was 9.0 and a faint H_2S odor could be detected throughout the experiment.

Figure 6 indicates that Cr(VI) was rapidly reduced by dissolved sulfides; 50% of the original Cr(VI) was reduced in less than five min in the presence of 10^{-3} M total sulfides. The reaction then slowed considerably but still went to essential completion after 27 h. The effect of pH on the rate of this reaction is not known. The predominant species of sulfide at this pH is HS^-. Like Fe(II), sulfides are also oxidized by O_2, but in this case the rate appears to be slower and the interference is not as great.

The significance of the reduction of Cr(VI) by sulfides lies in the fact that H_2S can be produced by decomposition of organic matter, by bacterial sulfate reduction, or by the discharge of certain industrial wastes. The Cr(III) produced by this reaction is then likely to be sorbed by suspended solids and removed from solution. The oxidation of sulfides by O_2 appears to be slow enough to allow their penetration for a short distance into aerobic waters, and it is in these boundary zones, such as at the thermocline, reduction of Cr(VI) is expected.

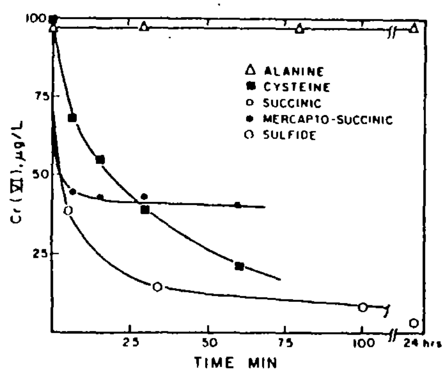


Fig. 6. Reduction of Cr(VI) by 10^{-3} M sulfides by pH 9.1, cysteine, alanine, and 10^{-3} M mercaptosuccinic acid

3.6. Reduction of Cr(VI) by Organic Compounds with Sulfhydryl Groups

The effects of certain organic compounds on Cr(VI) were determined. The compounds chosen were the amino acid alanine, the sulfur-bearing amino acid cysteine, succinic acid, and mercaptosuccinic acid. In each case, the reference solution was made 10^{-3} M in the compound being tested.

Figure 6 indicates that cysteine and mercapto-succinic acid reduced Cr(VI) at a rapid rate while no reduction could be detected in solutions containing alanine or succinic acid. Mercaptosuccinic acid is apparently subject to oxidation by O_2 as well, since little or no reduction occurred after 10 min with 40% of the Cr(VI) remaining.

While it is unlikely that sulfhydryl-bearing compounds are abundant enough in natural waters to affect the distribution of Cr, a possibility exists that Cr(VI) taken up by aquatic organisms is reduced by, and inactivates, coenzymes bearing this group.

3.7. Reduction of Cr(VI) in Natural Water Samples

Cr(VI) was added to natural water samples to determine the effects of natural organics and to detect any naturally occurring reducing agents. The sources of these samples were Lake Mendota, Madison, Wisconsin, with 5 units of true color, and Waunakee Marsh, located north of Lake Mendota, with 25 units of true color. Each sample was divided in half, with one portion initially filtered through 0.22 μpore size filters and the other left unfiltered with aliquots filtered before Cr(VI) analysis. Each sample had an initial Cr(VI) concentration of 100 μg l^{-1}.

The results presented in Table VI indicate that no significant reduction of Cr(VI) occurred in water from Lake Mendota or from Waunakee Marsh. The rate of loss of

A Numerical Method for Computing Equilibria in Aqueous Chemical Systems

Francois Morel[1] and James Morgan

W. M. Keck Laboratories, California Institute of Technology, Pasadena, Calif. 91109

■ A general purpose computer program especially adapted to the study of acid base and coordinative interactions and dissolution and precipitation in aqueous systems has been developed. The program uses the stability constant approach and the Newton-Raphson method for digital computation of equilibria. It is able to handle numerous species and to find the equilibrium set of solids. Gas phases are considered to be at constant partial pressures. The method is explained by use of the aqueous iron(III) calcium carbonate-phosphate system as an example. An application of the program to a system of 788 soluble species, 83 possible solids, and one gas-phase component is given as an illustration.

Equilibrium models can be very useful for understanding the various processes dissolution and precipitation, oxidation and reduction, acid base and coordinative interactions which govern the chemical composition of natural waters (Stumm and Morgan, 1970). A classical example of such an equilibrium model is the seawater model of Sillén (1961).

Typically, these models require the computation of equilibrium compositions for systems containing numerous species distributed among an aqueous phase, a gas phase, and several solid phases. For any given model, the temperature and the pressure can generally be taken as constants. Exchange of matter with the surroundings being neglected and ideality being assumed, the thermodynamic treatment of such closed systems is straightforward (Denbigh, 1966), and the equilibrium composition is given by the minimum of the Gibbs free energy function or, equivalently, by the mass action laws, both subject to the constraints of the mole balance conditions.

We have been interested in developing a general purpose computer program especially adapted to solving these types of chemical equilibrium problems. Two main choices have to be made in the development of such a program: First, the choice of a notation that will allow the description of the system in algebraic terms and the setting up of the equations; second, the choice of a method to solve the equilibrium problem.

Every possible kind of notation has been proposed in the literature from the most particular one which identifies every chemical species under a special symbol, to the most general one where elements of multidimensional tensors represent the species and their formulas. Because our prime interest is with coordination processes we have chosen to differentiate between metals (M), ligands (L), and complexes (C). Since acid base interactions are of special interest to us, the proton has been given a special symbol (H). Gas and solid phases interact with the soluble species in a fairly similar way and they are given a single symbolic representation (S). We feel that this notation is general enough to allow the treatment of most of the systems we are interested in and that it is particular enough to facilitate the translation of a particular chemical problem into a general algebraic one. The metals and the ligands are thus logically taken as the components of the system and this division of the components into two families allows an unusually compact description of the system in a tableau form. This compactness is important in enabling a large number of species (up to a few thousand) to be handled.

To solve the chemical equilibrium problem, two principal techniques can be distinguished. First, the so-called equilibrium constant approach which consists of solving the set of nonlinear equations provided by the mass law and the mole balance equations. This method was pioneered by such workers as Brinkley (1947), and its most prominent application to aqueous systems is the Haltafall program developed by Sillén and his co-workers (Ingri et al., 1967). The second technique was first proposed by Dantzig and co-workers (White et al., 1958) and consists of directly minimizing the Gibbs free energy function subject to the constraints of the mole balance equations. This method was applied to large multiphasic systems by Shapiro (1964). A fairly complete review of the two methods has been given by Zeleznik and Gordon (1968).

We have chosen to use the equilibrium constant approach. The determining factor in choosing this method was that it allows reduction of the number of principal variables. In our case, for example, the concentrations of the complexes can be expressed as a function of the free metal and free ligand concentrations by the mass law equations, and the problem is thus reduced to finding this set of free metal and free ligand concentrations that will satisfy the mole balance conditions. This is done by use of the Newton-Raphson method for systems of nonlinear equations.

As can be seen, our method is just the application of well-known principles to a particular class of problems. Our goal is simply to present what we have found to be an efficient and reliable tool for solving a fairly general and important class of chemical equilibrium problems in order to help others develop similar tools.

By use of examples, the notation and the systematic setting-up of the equations, both in the absence and in the presence of solids, will be presented. An iterative procedure to find the equilibrium solid phases will then be shown. An abridged description of the program will finally be given, followed by an example demonstrating the possibilities of the method.

Description of the System

To derive a general method of computation one has to choose some systematic notation that will describe the chemical system in algebraic terms. The notation that we have chosen differentiates metals and ligands and represents the chemical system in a tableau form. For example, the iron(III) calcium carbonate phosphate system in water is represented in Figure 1. The values in parentheses are the logarithms of the concentration stability constants for formation of aqueous species from their components and for the dissolution of solid or gaseous species. The stability constants used here and in the other examples in this paper apply to a constant ionic medium of 0.5M. They have been selected mainly from the compilations of Sillén and Martell (1964), Ringbom (1963), and Garrels and Christ (1965). When experimental values for 0.5M ionic medium were not available, approximate values were obtained by applying Ringbom's ionic strength corrections (Ringbom, 1963). Our equilibrium constant values are not intended to be critical selections; applications to specific problems will require critical examination of the appropriate thermodynamic data for particular solid phases and aqueous species.

The choice of independent components is, of course, partly arbitrary. For example, either carbonate (CO_3^{2-}) or bicarbonate (HCO_3^-) could be chosen as a component, but both of them could not be chosen at the same time if the proton (H^+) is also to be a component; (CO_3^{2-}), (HCO_3^-), and (H^+) are not independent. We have chosen the least-protonated forms of the ligands and the unhydrolyzed forms of the metals as the components of the system.

The advantage of such a presentation is twofold: It allows a compact writing of large systems, and it has a pedagogic and practical value in pointing out the possible complex formations. The main disadvantage of the presentation is that it is not completely general: Unless special provision is made, no complex involving two different metals or two different ligands can be considered. Because H^+ and OH^- often react with another metal or ligand in complex formation, the general complex formula we use does allow this possibility. A metal M_i and a ligand L_j can form a complex C_{ijk} of the form

$$C_{ijk} \equiv (M_i)_\alpha (L_j)_\beta (H)_\gamma$$

where i is an index specifying the metal, j is an index specifying the ligand, k is an index specifying the different $M_i L_j$ complexes in an arbitrary order, α (in fact, α_{ijk}) is the stoichiometric coefficient of the metal in the formula of C_{ijk}, β (in fact, β_{ijk}) is the stoichiometric coefficient of the ligand in the formula C_{ijk}, and γ (in fact, γ_{ijk}) is the stoichiometric coefficient of the hydrogen ion, H^+, or hydroxide ion, OH^-, in the formula of C_{ijk}. For H^+ in the complex $\gamma > 0$; for OH^- in the complex $\gamma < 0$; so that the formula of C_{ijk} may also be:

$$C_{ijk} \equiv (M_i)_\alpha (L_j)_\beta (OH)_{-\gamma}$$

Then, with the appropriate definition of the stability constant K_{ijk}, one can always write the mass action law:

$$[C_{ijk}] = K_{ijk} \cdot [M_i]^\alpha \cdot [L_j]^\beta \cdot [H]^\gamma \qquad (1)$$

This contains implicitly the result $[OH] = K_w/[H]$ in case $\gamma_{ijk} < 0$.

It should be pointed out that with this notation H^+ is identified at the same time both as H and conventionally as the last metal, M_3, in our example (Figure 2).

In the same way, the solids can be described by

$$S_{ij} \equiv (M_i)_\delta (L_j)_\eta (H)_\lambda$$

or

$$S_{ij} \equiv (M_i)_\delta (L_j)_\eta (OH)_{-\lambda}$$

where δ, η, λ (in fact, δ_{ij}, η_{ij}, λ_{ij}) have definitions similar to those of α, β, γ.

Metals	Ligands: CO_3^{2-}		PO_4^{3-}		OH^-	
Ca^{2+}	$CaCO_3$	(1 95)	$CaHPO_4$	(12 6)	$CaOH^+$	(0 9)
	$CaHCO_3^+$	(10 58)				
	$CaCO_3(s)$	(−7 0)	$Ca_5(PO_4)_3OH(s)$	(−51 5)	$Ca(OH)_2(s)$	(−4 9)
Fe^{3+}	No important complex or solid known		$FeHPO_4^+$	(18 0)	$FeOH^{2+}$	(11 3)
					$Fe(OH)_2^+$	(22 0)
					$Fe(OH)_4^-$	(31 0)
			$FePO_4(s)$	(−23 0)	$Fe(OH)_3(s)$	(−36 0)
H^+	HCO_3^-	(9 6)	HPO_4^{2-}	(11 8)	Water	
	H_2CO_3	(15 4)	$H_2PO_4^-$	(18 5)		
	$CO_2(g)$	(−17 0)	H_3PO_4	(20 4)		

Figure 1. Tableau representation for the iron(III)-Ca^{2+}-CO_3^{2-}-PO_4^{3-} system in water

Equilibrium constant (0.5M ionic medium) for formation of aqueous species and for dissolution of solids and gases are given in parentheses, as the logarithm

	L_1	L_2	$L_3(=OH)$
M_1	$C_{111} \equiv (M_1)(L_1)$	$C_{121} \equiv (M_1)(L_2)(H)$	$C_{131} \equiv (M_1)(L_3)$
	$C_{112} \equiv (M_1)(L_1)(H)$		
	$S_{11} \equiv (M_1)(L_1)$	$S_{12} \equiv (M_1)_5(L_2)_3(OH)$	$S_{13} \equiv (M_1)(L_3)_2$
M_2		$C_{221} \equiv (M_2)(L_2)(H)$	$C_{231} \equiv (M_2)(L_3)$
			$C_{232} \equiv (M_2)(L_3)_2$
			$C_{233} \equiv (M_2)(L_3)_4$
		$S_{22} \equiv (M_2)(L_2)$	$S_{23} \equiv (M_2)(L_3)_3$
$M_3(=H)$	$C_{311} \equiv (M_3)(L_1)$	$C_{321} \equiv (M_3)(L_2)$	
	$C_{312} \equiv (M_3)_2(L_1)$	$C_{322} \equiv (M_3)_2(L_2)$	
	$S_{31} \equiv (M_3)_2(L_1)$	$C_{323} \equiv (M_3)_3(L_2)$	

Figure 2. General representation (aqueous species, solids, and gas) of the system of Figure 1 in terms of metals M_i, ligands L_j, H ions, and OH ions

[1] To whom correspondence should be addressed.

It should be noted that this notation does not allow the formation of two different solids involving a metal and a ligand (there is no third index). This is being modified in newer versions of the program.

There is no computational reason to differentiate between solids and components of gas phases at constant partial pressure since in both cases we can write the solubility equation in the general form:

$$k = [M_i]^{\delta} \cdot [L_j]^{\eta} \cdot [H]^{\lambda} \qquad (2)$$

where k (in fact, k_{ij}) is corrected by the right power of K_w in case $\lambda < 0$ and contains the partial pressure in case we are dealing with a gas phase. Consequently both solid and gas phase components will be referred to by the letter S.

Now Figure 1 can be rewritten in general terms, as shown in Figure 2.

In this tableau the three-dimensional arrays of numbers K, α, β, γ and the two-dimensional arrays k, δ, η, λ completely describe the general chemical properties of the system. Figure 3 shows these eight arrays of numbers.

To be able to solve a problem we need as many equations as we have unknowns. It is convenient to consider the concentrations of the complexes as secondary unknowns given from the principal unknowns M_i, L_j, and H by Equation 1. We thus need an equation for every metal ($\neq$H), for every ligand ($\neq$OH), and for the proton. These equations are given by the particular conditions of the system in different cases.

Case Where No Solid Is Present. Let us first suppose that in our example the system has been made by adding 10^{-4} mole of ferric phosphate ($FePO_4$), 10^{-4} mole of calcium hydroxide, $Ca(OH)_2$, and 10^{-3} mole of carbon dioxide (CO_2) in 1 liter of water. Suppose also that we know that no solid phase is present and that we study the equilibrium before the gas phase has had time to form. We can then write down the mole balance equation for each metal ($\neq$H) and each ligand ($\neq$OH).

$$M_1: 10^{-4} = [M_1] + [C_{111}] + [C_{112}] + [C_{121}] + [C_{131}] \qquad (3.1)$$

$$M_2: 10^{-4} = [M_2] + [C_{221}] + [C_{231}] + [C_{232}] + [C_{233}] \qquad (3.2)$$

$$L_1: 10^{-3} = [L_1] + [C_{111}] + [C_{112}] + [C_{311}] + [C_{312}] \qquad (3.3)$$

$$L_2: 10^{-4} = [L_2] + [C_{121}] + [C_{221}] + [C_{321}] + [C_{322}] + [C_{323}] \qquad (3.4)$$

In general,

$$TOTM_i = [M_i] + \sum_{j,k} \alpha_{ijk}[C_{ijk}] \text{ (sum on line } i \text{ of Figure 2)}$$

$$TOTL_j = [L_j] + \sum_{i,k} \beta_{ijk}[C_{ijk}] \text{ (sum on column } j \text{ of Figure 2)} \qquad (3)$$

where $TOTM_i$ and $TOTL_j$ are the analytical or total concentrations of the metal M_i and the ligand L_j, respectively.

We need one more equation for (H); different cases can be entertained. First, we might know the pH either because we have measured it experimentally or because we have imposed it—practically or conceptually—by adding a buffer which has no interaction (other than through the proton concentration) with the chemicals we are interested in. In this case the problem is trivial: (H) is fixed (pH = 5.21 in our example) and we do not need any other equation. If the pH is not known, we have to compute it by using either the electroneutrality or the proton condition. These two equations are known to be mathematically (not computationally) equivalent and can be deduced from each other by combination with the mole balances (Equations 3). For the electroneutrality condition to be written, we need to include the charges of each metal and each ligand in the data and then to compute the charge of every complex. The electroneutrality equation also has the computational disadvantage that for any salt present in high concentration and essentially free, we will add and subtract the concentrations of the cations and anions, respectively, in such a way as to create a round-off error that might not be negligible.

For these reasons we have judged it preferable to use the proton condition:

$$\sum \text{"acids" put into the system} - \sum \text{"bases" put into the system} = \sum \text{all species containing } H^+ - \sum \text{all species containing } OH^-$$

This equation comes from the conservation equations of H^+ and OH^- and from the fact that for any proton produced by the dissociation of water there is a corresponding hydroxide ion produced.

The definitions of "acids" and "bases" are, of course, relative to our choice of metals and ligands—e.g., if $CO_3^{2-} \equiv L_1$ then HCO_3^- (HL_1) and CO_2 (H_2L_1) are acids; if $CO_2 \equiv L_1$ then HCO_3^- (OHL_1) and CO_3^{2-} [$(OH)_2L_1$] are bases.

With our notation, the proton condition can be written in the general form:

$$TOTH = [H] - [OH] + \sum_{\substack{\text{last row} \\ j,k}} \alpha_{ijk}[C_{ijk}] - \sum_{\substack{\text{last column} \\ i,k}} \beta_{ijk}[C_{ijk}] + \sum_{i,j,k} \gamma_{ijk}[C_{ijk}] \qquad (4)$$

$TOTH$ is an input into the problem whose value will correspond to the experimental base-neutralizing capacity (respective acid-neutralizing capacity) of the system if the components are written in their least-protonated (respective most protonated) form. If only neutral components are chosen, the proton condition is strictly identical to the electroneutrality condition. In our example, if $CO_3^{2-} \equiv L_1$ and $Ca(OH)_2 \equiv M_1$ then $TOTH$ = base-neutralizing capacity; if $CO_2 \equiv L_1$ and $Ca^{2+} \equiv M_1$ then $TOTH$ = acid-neutralizing capacity. Since in this case our choice is mixed ($CO_3^{2-} \equiv L_1$ and $Ca^{2+} \equiv M_1$) $TOTH$ has no direct experimental meaning.

In our particular example the proton condition is written:

$$TOTH = [H] - [OH] + [C_{311}] + 2[C_{312}] + [C_{321}] + 2[C_{322}] + 3[C_{323}] - [C_{131}] - [C_{231}] - 2[C_{232}] - 3[C_{233}] + [C_{112}] + [C_{121}] + [C_{221}] \qquad (4.1)$$

where $TOTH = 2[CO_3]_T - 2[Ca(OH)_2]_T = 2 \times 10^{-3} - 2 \times 10^{-4} = 1.8 \times 10^{-3}$.

Equations 3 and 4 completely define the system once the secondary variables have been replaced by their values (Equation 1). To solve this system of nonlinear equations we have used a slightly modified Newton-Raphson method. This involves writing the general expressions of the derivatives of Equations 3 and 4 with respect to the principal variables (M_i), (L_j), and (H). It is a simple matter; the expressions are given in the Appendix. The Newton-Raphson method starts from an initial guess and improves it by use of the iterative procedure

$$\vec{X}_{n+1} = \vec{X}_n - J_n^{-1}\vec{Y}_n$$

Where $\vec{X}_n$ is the approximation of the solution vector $\vec{X}$ in the system $\vec{Y}(\vec{X}) = 0$ at the nth iteration and $\vec{X}_{n+1}$ is its improvement at the next iteration. J is the Jacobian matrix of the system. $\vec{Y}_n$ is $\vec{Y}(\vec{X}_n)$ and J_n is $J(\vec{X}_n)$. For details see, for example, Isaacson and Keller (1966).

To avoid the convergence toward a negative solution we have slightly modified this iterative procedure and developed the empirical rule to simply divide by 10 any concentration that the Newton-Raphson iteration would make negative—i.e., if $X_{n+1}^i < 0$ take instead $(X_{n+1}^i)' = X_n^i/10$. This "trick" seems to work well. Table I shows how the solution of our particular example [$10^{-4}M$ $FePO_4$; $10^{-4}M$ $Ca(OH)_2$; $10^{-3}M$ CO_2] was found, starting with the initial guess that each free metal and each free ligand concentration was $10^{-8}M$ at equilibrium.

At the tenth iteration the values were judged to verify the equations satisfactorily. Specifically: |right-hand side of Eq. 3 − left-hand side of Eq. 3| ≤ 10^{-4} × left-hand side, Eq. 3 and a similar condition for Equation 4. The negative logarithm of the concentrations of every species at equilibrium is shown in Figure 4.

Case Where Known Solid Phases or Gas-Phase Components at Fixed Partial Pressure Are Present. In continuing to work on our iron(III) calcium carbonate phosphate system, suppose that the particular conditions are: $p_{CO_2} = 3 \times 10^{-4}$ atm; $[Ca_5(PO_4)_3OH]_T = 2 \times 10^{-4}M$; $[FePO_4]_T = 10^{-3}M$; $[H_3PO_4]_T = 3 \times 10^{-3}M$; and if we know that the solid phases $Ca_5OH(PO_4)_3$, S_{13}, and $FePO_4$, S_{23}, are present at equilibrium, then Equations 1 defining the secondary variables, $[C_{ijk}]$, are still the same. Defining $[S_{ij}]$ as the number of moles of solid S_{ij} or gas S_{ij} per liter of solution (a bizarre but convenient definition), we can write the mole balance equations:

$$M_1: TOTM_1 = 5\,[S_{13}] + (\text{rhs, Equation 3.1}) \qquad (5.1)$$

$$M_2: TOTM_2 = [S_{23}] + (\text{rhs, Equation 3.2}) \qquad (5.2)$$

$$L_1: TOTL_1 = [S_{31}] + (\text{rhs, Equation 3.3}) \qquad (5.3)$$

$$L_2: TOTL_2 = 3[S_{13}] + [S_{23}] + (\text{rhs, Equation 3.4}) \qquad (5.4)$$

and the proton condition:

$$H: TOTH = -[S_{13}] + 2[S_{31}] + (\text{rhs, 4.1}) \qquad (6.1)$$

The general Equations 5 and 6 are easily written similarly to 3 and 4:

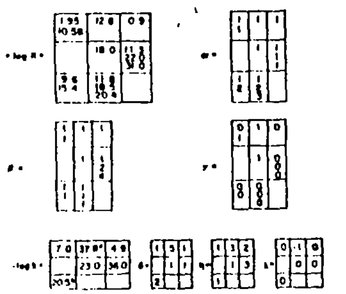


Figure 3. The arrays of stability constants and stoichiometric coefficients required to describe the iron(III) Ca^{2+} CO_3^{2-} PO_4^{3-} system in water

[a] Computed for $K_w = 10^{-13.7}$. [b] Computed for $p_{CO_2} = 10^{-3.5}$ atm

Table I. Successive Computed Solutions for the Equilibrium Values of Free Metals and Ligands for an Iron(III) Ca^{2+}–CO_3^{2-}–PO_4^{3-} System under Conditions Where No Solid Forms and H_2CO_3 Is Considered a Nonvolatile Species

Components: $[FePO_4]_T = 10^{-4}M$; $[Ca(OH)_2]_T = 10^{-4}M$; $[CO_2]_T = 10^{-3}M$. The equilibrium composition is computed with sufficient accuracy by the tenth iteration

Iteration no.	$[M_1]$	$[M_2]$	$[L_1]$	$[L_2]$	[H]
0	1.00×10^{-8}	1.00×10^{-8}	1.00×10^{-8}	1.00×10^{-8}	1.00×10^{-8}
1	1.00×10^{-4}	4.90×10^{-13}	2.43×10^{-8}	2.89×10^{-10}	1.00×10^{-4}
2	9.89×10^{-5}	2.59×10^{-12}	1.80×10^{-8}	7.12×10^{-11}	1.26×10^{-4}
3	9.90×10^{-5}	6.30×10^{-12}	1.80×10^{-8}	2.61×10^{-11}	2.80×10^{-6}
4	9.92×10^{-5}	1.39×10^{-10}	1.80×10^{-7}	2.61×10^{-11}	3.36×10^{-7}
5	9.98×10^{-5}	3.87×10^{-9}	1.80×10^{-8}	2.61×10^{-11}	5.02×10^{-8}
6	9.98×10^{-5}	9.66×10^{-10}	8.06×10^{-9}	2.61×10^{-14}	5.64×10^{-6}
7	9.98×10^{-5}	1.88×10^{-10}	8.42×10^{-9}	4.79×10^{-15}	6.17×10^{-6}
8	9.98×10^{-5}	5.94×10^{-11}	8.46×10^{-9}	8.13×10^{-15}	6.11×10^{-6}
9	9.98×10^{-5}	9.33×10^{-12}	8.46×10^{-9}	8.19×10^{-15}	6.11×10^{-6}
10	9.98×10^{-5}	9.33×10^{-12}	8.46×10^{-9}	8.19×10^{-15}	6.11×10^{-6}

	$pL_1 = 8.07$	$pL_2 = 14.09$	$pL_3 = 8.49$
$pM_1 = 4.00$	$pC_{111} = 10.12$; $pC_{112} = 6.71$	$pC_{121} = 10.70$	$pC_{131} = 11.59$
$pM_2 = 11.03$		$pC_{221} = 12.33$	$pC_{231} = 8.22$; $pC_{232} = 6.01$; $pC_{233} = 13.99$
$pM_3 = 5.21$	$pC_{311} = 3.68$; $pC_{312} = 3.10$	$pC_{321} = 7.50$; $pC_{322} = 6.01$; $pC_{323} = 9.33$	

Figure 4. Results of equilibrium computation for an iron(III) Ca^{2+} CO_3^{2-} PO_4^{3-} system in absence of solid or gas phases

The tableau gives the negative logarithm (p[ ]) of each metal ion, ligand, protonated ligand, and complex at equilibrium

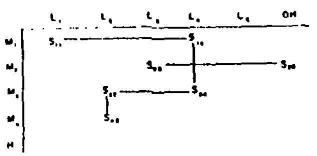


Figure 5. Examples of "connected" solids

S_{11}, S_{14} are connected; S_{33}, S_{41} are connected; S_{11}, S_{33} are also connected

There are two families of connected solids: $\begin{cases} S_{22}, S_{24} \\ S_{11}, S_{14}, S_{34}, S_{33}, S_{41} \end{cases}$

$$TOTM_i = [M_i] + \sum_j b_{ij}[S_{ij}] + \sum_{j,k} \alpha_{ijk}[C_{ijk}]$$
$$TOTL_j = [L_j] + \sum_i \eta_{ij}[S_{ij}] + \sum_{i,k} \beta_{ijk}[C_{ijk}] \quad (5)$$

$$TOTH = [H] - [OH] + \sum_{\substack{\text{last row}\\ j}} b_{ij}[S_{ij}] + \sum_{\substack{\text{last row}\\ j,k}} \alpha_{ijk}[C_{ijk}] - \sum_{\substack{\text{last column}\\ i}} \eta_{ij}[S_{ij}] - \sum_{\substack{\text{last column}\\ i,k}} \beta_{ijk}[C_{ijk}] + \sum_{ij} \lambda_{ij}[S_{ij}] + \sum_{ijk} \gamma_{ijk}[C_{ijk}] \quad (6)$$

Let us come back to our example. Not knowing what the value of $[CO_2(g)]_T$ is, we can take it to be some sufficiently large number, say $[CO_2]_T = 0.1M$; then

$$TOTM_1 = 5[Ca_5(PO_4)_3OH]_T = 10^{-2}M$$
$$TOTM_2 = [FePO_4]_T = 10^{-3}M$$
$$TOTL_1 = [CO_2]_T = 10^{-1}M$$
$$TOTL_3 = 3[Ca_5(PO_4)_3OH]_T + [FePO_4]_T + [H_3PO_4]_T = 10^{-2}M$$
$$TOTH = -[Ca_5(PO_4)_3OH]_T + 2[CO_2]_T + 3[H_3PO_4]_T = 2.07 \times 10^{-1}M$$

We have introduced three new unknowns $[S_{13}]$, $[S_{23}]$, $[S_{31}]$; correspondingly, we can write three new equations of the type 2:

$$S_{13}: [M_1]^5[L_3]^3[H]^{-1} = 10^{-37.0} \quad (2.1)$$
$$S_{23}: [M_2][L_3] = 10^{-22.0} \quad (2.2)$$
$$S_{31}: [H]^2[L_1] = 10^{-18.0} \quad (2.3)$$

Rather than to solve this new system with the new unknowns $[S_{ij}]$ (which are, in fact, only formally defined), we have chosen to eliminate systematically those unknowns and thus to reduce the number of equations.

We shall say that solids are connected whenever they share a common metal or a common ligand. We shall also say that solids are connected whenever they are connected to a common solid (Figure 5).

Whenever we have a family of connected solids, we can arbitrarily select a principal variable among the metals and the ligands involved in such a family and, using Equations 2, define the other metals and ligands involved as secondary variables. For example, choosing (H) and (L_3) as principal variables in our system, we get:

$$\text{from (2.3): } [L_1] = 10^{-18.0} \cdot [H]^{-2} \quad (7.1)$$
$$\text{from (2.2): } [M_2] = 10^{-22.0} \cdot [L_3]^{-1} \quad (7.2)$$
$$\text{from (2.1): } [M_1] = 10^{-37.0/5} \cdot [L_3]^{-3/5}[H]^{1/5} \quad (7.3)$$

In general:

$$[\text{secondary variable}] = \mu \cdot [\text{principal variable}]^{\nu} \cdot [H]^{\nu'} \quad (7)$$

For simplicity [H] is always chosen as a principal variable and the coefficients μ, ν, and ν' can be computed on a systematic basis. It can be easily verified that the coefficients ν and ν' so defined for each new secondary variable are those that will eliminate the $[S_{ij}]$ from Equations 5 and 6:

(equation with $[S_{ij}]$ eliminated) =

(equation of principal variable) +

$\sum \nu \cdot$ (equation of connected secondary variable)

$\left[+ \sum \nu' \text{ (equation of any secondary variable) only for proton condition}\right]$ (8)

In our example:

Equation 5.4 − 3/5(5.1) − (5.2) gives:

$$TOTL_3 - 3/5\, TOTM_1 - TOTM_2 = (\text{rhs}, 3.4) - 3/5(\text{rhs}, 3.1) - (\text{rhs}, 3.2) \quad (8.1)$$

and

Equation 6.1 + 1/5(5.1) − 2(5.3) gives:

$$TOTH + 1/5\, TOTM_1 - 2TOTL_1 = (\text{rhs}, 4.1) + 1/5(\text{rhs}, 3.1) - 2(\text{rhs}, 3.3) \quad (8.2)$$

We then have two equations (8.1 and 8.2) and two principal unknowns (H and L_3). The secondary unknowns are given by Equations 1 and 7. The derivatives of those equations with respect to the principal variables are easily computed from the derivatives of Equations 3 and 4 (see Appendix). The Newton-Raphson method can then be used as before and Table II shows how the solution of our example ($p_{CO_2} = 3 \times 10^{-4}$ atm; $2 \times 10^{-3}M$ apatite; $10^{-3}M$ $FePO_4$; $3 \times 10^{-3}M$ H_3PO_4) was found starting with the initial guess that every free metal and every free ligand were $10^{-5}M$ at equilibrium (in fact, only [H] and $[L_3]$ are important since the others are computed as secondary variables).

	$pL_1 = 9.63$	$pL_2 = 10.01$	$pL_3 = 8.27$
$pM_1 = 2.64$	$pC_{111} = 10.32$; $pC_{112} = 7.12$	$pC_{121} = 5.48$	$pC_{131} = 10.00$
$pM_2 = 12.99$		$pC_{221} = 10.43$	$pC_{231} = 9.96$; $pC_{232} = 7.53$; $pC_{233} = 15.07$
$pM_3 = 5.43$	$pC_{311} = 5.46$; $pC_{312} = 5.09$	$pC_{321} = 3.64$; $pC_{322} = 2.37$; $pC_{323} = 5.90$	

Figure 6. Equilibrium composition of the aqueous phase of the iron(III)–Ca^{2+}–CO_3^{2-}–PO_4^{3-} system with $p_{CO_2} = 3 \times 10^{-4}$ atm and with $Ca_5OH(PO_4)_3(s)$ and $FePO_4(s)$ existing at equilibrium

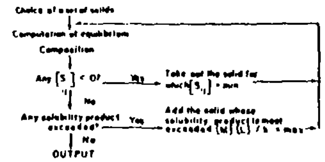


Figure 7. Routine for modifying the existing set of solids in a system at each stage in the computation

At the tenth iteration, the values were judged to verify the equations satisfactorily. The negative logarithms of the concentrations of every species at equilibrium are shown in Figure 6.

Case Where the Solid Phases Present Are Unknown. It is not *always possible to know, a priori, which solid phases are actually present at equilibrium*; we might guess that a solid is present while it is in fact completely dissolved at equilibrium or, reciprocally, we might not foresee the precipitation of a certain solid. In the first of those cases the system of equations has a solution that corresponds to a negative $[S_{ij}]$. On the other hand, if we have not foreseen the presence of a solid that does exist at equilibrium, the set of concentrations that solves the problem simply exceeds the corresponding solubility product. In either of those cases a solution can be computed on which the chosen set of solids can be tested. One can then modify this choice and start a new computation. This process is repeated until, hopefully, the right set of solids is found. The following diagram shows how our program modifies the set of solids after each computation. Other ways are, of course, possible; this one seems to work well (Figure 7).

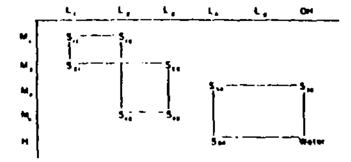


Figure 8. Examples of "closed" families of connected solids

S_{11}, S_{12}, S_{32}, S_{43}, S_{33}, S_{31}, S_{41} is a "closed" family of connected solids. S_{34}, S_{54}, S_{51} is also a "closed" family of connected solids since H and OH are not independent. (Water = S_{56})

We have chosen to "precipitate" and "dissolve" solids one by one to change the system as little as possible and to use the solution of the preceding computation as a good guess to start the new one. We have also chosen to "dissolve" solids before "precipitating" them to avoid the creation of a "closed" family of connected solids (Figure 8).

Such families are defined by

"number of metals" + "number of ligands" ≤ "number of solids"

and they can be shown to be, in general, impossible merel applying the Gibbs phase rule. In the example of Figure 8 coefficients λ are all supposed to be zero. If the pH is arbitrarily fixed one needs an additional degree of freedom and the examples are valid even with nonzero λ coefficients.

The scheme of Figure 7 works only for solids and no provision has been made in the program to compute equilibrium of gas phases at constant volume. It is thus important to impose a sufficiently high total concentration of the known gas-phase components to avoid trouble with the "dissolving" routine. Figure 9 shows how the scheme of Figure 7 worked in the example previously treated ($p_{CO_2} = 3 \times 10^{-4}$ atm; $2 \times 10^{-3}M$ apatite; $10^{-3}M$ $FePO_4$; $3 \times 10^{-3}M$ H_3PO_4) where the solids S_{11}, $CaCO_3$, and S_{22}, $Fe(OH)_3$, were imposed instead of S_{13} and S_{23}.

These numbers at iteration 25 are, of course, identical to those found before (Table II). Cv means that the program converged at that iteration—i.e., the values on that line are the mathematical solution of the system when the corresponding solids are imposed up to that point. For example, at the third iteration, S_{11} and S_{22} are imposed; at the 20th iteration, S_{13}, S_{22}, and S_{23} are imposed.

Iteration no.	$[M_1]$	$[M_2]$	$[L_1]$	$[L_3]$	[H]
0	3.16×10^{-3}	1.26×10^{-19}	$3.16 \times 10^{[illegible]}$	$1.00 \times 10^{[illegible]}$	$1.00 \times 10^{[illegible]}$
3 (cv)	9.44×10^{-3}	6.50×10^{-19}	$1.06 \times 10^{[illegible]}$	8.00×10^{-7}	$1.73 \times 10^{[illegible]}$
Solid S_{11} "dissolves"					
6 (cv)	$9.41 \times 10^{[illegible]}$	7.56×10^{-19}	$9.57 \times 10^{[illegible]}$	7.58×10^{-7}	$1.82 \times 10^{[illegible]}$
Solid S_{13} "precipitates"					
14 (cv)	$3.01 \times 10^{[illegible]}$	1.63×10^{-11}	1.23×10^{-10}	6.88×10^{-11}	$5.06 \times 10^{[illegible]}$
Solid S_{23} "precipitates"					
20 (cv)	$4.78 \times 10^{[illegible]}$	1.48×10^{-11}	$1.32 \times 10^{[illegible]}$	6.77×10^{-10}	$4.89 \times 10^{[illegible]}$
Solid S_{22} "dissolves"					
25 (cv)	$2.30 \times 10^{[illegible]}$	1.03×10^{-12}	2.33×10^{-10}	9.67×10^{-11}	$3.68 \times 10^{[illegible]}$

Figure 9. Illustration of successive modifications of solids in an iron(III)–Ca^{2+}–CO_3^{2-}–PO_4^{3-} system where an initially imposed set of solids was not the equilibrium set [same conditions as in Table II except that the solids $CaCO_3(s)$ and $Fe(OH)_3(s)$ were imposed at the outset of the computation]

At the 25th iteration the correct set of solids has been formed and the equilibrium composition is attained

Table II. Successive Computed Solutions for the Equilibrium Values of Free Metals and Ligands in an Iron(III) Ca^{2+} CO_3^{2-} PO_4^{3-} System Where p_{CO_2} Is Fixed and the Phases $Ca_5OH(PO_4)_3$ (s) and $FePO_4$(s) Are at Equilibrium

Components: $[Ca_5OH(PO_4)_3]_T = 2 \times 10^{-3}M$; $[FePO_4]_T = 10^{-3}M$; $[H_3PO_4]_T = 3 \times 10^{-3}M$; $p_{CO_2} = 3 \times 10^{-4}$ atm. The equilibrium composition is computed with sufficient accuracy by the tenth iteration.

Iteration no.	$[M_1]$	$[M_2]$	$[L_1]$	$[L_2]$	[H]
0	4.36×10^{-3}	1.00×10^{-16}	3.16×10^{-4}	1.00×10^{-8}	1.00×10^{-8}
1	1.02×10^{-3}	4.99×10^{-17}	9.90×10^{-7}	2.00×10^{-7}	5.65×10^{-9}
2	5.38×10^{-4}	4.99×10^{-16}	6.01×10^{-8}	2.00×10^{-8}	2.29×10^{-7}
3	2.77×10^{-4}	4.99×10^{-15}	4.61×10^{-9}	2.00×10^{-9}	8.28×10^{-7}
4	1.41×10^{-4}	4.99×10^{-14}	3.97×10^{-10}	2.00×10^{-10}	2.82×10^{-6}
5	5.54×10^{-3}	4.41×10^{-18}	2.15×10^{-10}	2.26×10^{-11}	3.83×10^{-6}
6	3.83×10^{-3}	1.94×10^{-18}	6.29×10^{-11}	5.14×10^{-11}	7.09×10^{-6}
7	2.62×10^{-3}	1.30×10^{-18}	2.47×10^{-10}	7.71×10^{-11}	3.58×10^{-6}
8	2.35×10^{-3}	1.06×10^{-18}	2.22×10^{-10}	9.43×10^{-11}	3.78×10^{-6}
9	2.30×10^{-3}	1.03×10^{-18}	2.33×10^{-10}	9.67×10^{-11}	3.68×10^{-6}
10	2.30×10^{-3}	1.03×10^{-18}	2.33×10^{-10}	9.67×10^{-11}	3.68×10^{-6}

Description of the Program. The program is written in FORTRAN and is usually run on an IBM 360/75 computer. It is made up of 11 principal subroutines organized in the following way (Figure 10):

INDAT is a subroutine that reads the data: general stoichiometric and thermodynamic data; special conditions of the problem; total concentrations of metals and ligands, pH, or *TOTH*; guesses for the free concentrations of metals and ligands and chosen sets of solids.

SOLIDO finds out if any solid is present; scans the tableau for families of connected solids; defines the principal and secondary variables; and computes the coefficients μ, ν, and ν'.

MLINSO computes the secondary variables *M* and *L* (other than *C*) in function of the principal variables using μ, ν, and ν'.

SCYZ computes the secondary variables, *C*, the mole balance equations for each metal and ligand ($\neq$ H or OH) and their derivatives with respect to every metal and ligand. By computing a mole balance equation, we mean finding the actual numerical difference between the sum of the concentrations of the soluble species and the imposed analytical (total) concentration of the same component. In the same way the derivatives are the numerical values obtained by replacing the concentrations by their molar values in the formal algebraic formulas of the derivatives.

SCHEH computes the proton condition equation, its derivatives with respect to every metal and ligand, and the derivatives of all the equations with respect to H.

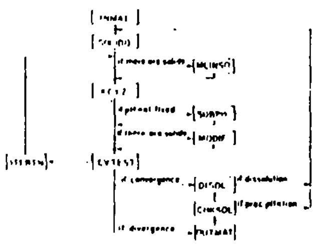


Figure 10. Chart showing the organization of the principal subroutines of the computer program

MODIF modifies the equations in accordance with our choice of principal and secondary variables i.e., eliminates the $[S_{ij}]$. It also modifies the derivatives accordingly.

CVTEST verifies that the number of iterations does not exceed any arbitrary number and checks whether or not the equations are satisfied within an arbitrary precision.

ITERIN performs the Newton-Raphson iteration using a Gaussian elimination without iterative improvement to solve the system of linear equations: $J_n(\bar{X}_n - \bar{X}_{n+1}) = \bar{Y}_n$.

DISOL computes the amount of every solid precipitated and verifies that none is negative. In case some are negative, the least-probable solid ($[S_{ij}]$ = minimum) is no longer imposed and the computation is restarted.

CHKSOL verifies that no solubility product has been exceeded. In case some are exceeded, the solid for which the driving force is greatest $[([M_i][L_j])/K_{ij}$ = maximum] is imposed and the computation is restarted.

OUTMAT prints the output. Metals, ligands, and complexes are printed in a matrix form.

Example of Computation. The following example shows the application of the program to an equilibrium computation involving 20 metals (+H), 31 ligands (+OH), 738 complexes, 83 possible solids, and one gas-phase component. Pressure, temperature, ionic strength, pH, and oxidation reduction state are all taken to be constant. Table III gives the list of the metals and the ligands (and their identifying numbers) involved with their imposed analytical (total) concentrations.

Such an example can be seen to have some of the characteristics of certain well-known natural systems. The first guesses for the free metal and the free ligand concentrations were all taken to be $10^{-9}M$. The chosen set of solids at the start of the computation and its subsequent modifications by the program are shown in Figure 11.

The final result was found at the 56th iteration. Figure 12 gives the tableau of the thermodynamic data and has been deposited with the American Chemical Society Microfilm Depository Service. Table IV gives the computed equilibrium concentrations.

It is worthwhile to note that the whole computation took a little less than 60 sec. Equilibrium solutions at other pH's were also computed with this result as a starting guess; it takes about 35 iterations to go from one pH to the next one, say 8 to 9. The computation was also made without fixing the pH. *TOTH* = −0.83*M*, found in the first computation, was imposed and the result (identical to Table IV) was obtained in 52 iterations ($10^{-9}M$ being the systematic first guess and the correct set of solids having been imposed). The storage space needed for the program itself is about 50,000 bytes while it takes about 90,000 bytes to store the data. In all the examples we have taken a systematic guess of $10^{-9}M$ for every free concentration, not because we could not find a better one, but to show that the domain of convergence is rather large in general.

The program has now been extensively tested on numerous small and large systems and we have been able to converge toward the solution in each case. The program is being currently modified to handle variations in the ionic strength and oxidation reduction reactions.

To vary the ionic strength, two sets of equilibrium constants are stored, one at *I* = 0.0*M*, the other one at *I* = 0.5*M*. An interpolation routine allows computation of the set of constants corresponding to an intermediate ionic strength. An iterative technique looping on the whole program is envisaged to correct the equilibrium constants to the computed ionic strength of the system.

The redox reactions are handled in several ways. One way involves the use of optional complexes ($NO_3^- \rightleftharpoons NH_4^+ + 3H_2O - 9H^+ - 8e^-$), or optional solids ($MnO_2 \rightleftharpoons Mn^{2+} + 4OH^- - 2e - 2H_2O$) whose equilibrium constants are given as a function of the *pε* of the system. Another way is to define new secondary variables ($[Fe^{2+}] = K[e^-][Fe^{3+}]$) much in the same way it has been shown for solids. The existing subroutines MLINSO and MODIF are used to handle these.

Table III. List of Metal Ions and Ligands (Identified by Number) and Their Total Concentrations (Solid, Aqueous, and Gas Phases) in a Hypothetical Model System of 20 Metals and 31 Ligands[a]

Metals

No.	Metal	Conc.	No.	Metal	Conc.
1	Ca^{2+}	10^[illegible]	11	Cd^{2+}	10^[illegible]
2	Mg^{2+}	10^[illegible]	12	Zn^{2+}	10^[illegible]
3	Sr^{2+}	10^[illegible]	13	Ni^{2+}	10^[illegible]
4	K^+	10^[illegible]	14	Hg^{2+}	10^[illegible]
5	Na^+	10^[illegible]	15	Pb^{2+}	10^[illegible]
6	Fe^{3+}	10^[illegible]	16	Co^{2+}	10^[illegible]
7	Fe^{2+}	10^[illegible]	17	Co^{3+}	10^[illegible]
8	Mn^{2+}	10^[illegible]	18	Ag^+	10^[illegible]
9	Cu^{2+}	10^[illegible]	19	Cr^{3+}	10^[illegible]
10	Ba^{2+}	10^[illegible]	20	Al^{3+}	10^[illegible]

Ligands

No.	Ligand	Conc.	No.	Ligand	Conc.	No.	Ligand	Conc.
1	CO_3^{2-}	10^[illegible]	11	$P_3O_{10}^{5-}$	10^[illegible]	21	DIP	10^[illegible]
2	SO_4^{2-}	10^[illegible]	12	$SiO(OH)_3^-$	10^[illegible]	22	SUSAL	10^[illegible]
3	Cl^-	10^[illegible]	13	$S_2O_3^{2-}$	10^[illegible]	23	GLY	10^[illegible]
4	F^-	10^[illegible]	14	AC	10^[illegible]	24	GLUT	10^[illegible]
5	Br^-	10^[illegible]	15	ACAC	10^[illegible]	25	PIC	10^[illegible]
6	I^-	10^[illegible]	16	CIT	10^[illegible]	26	NTA	10^[illegible]
7	NH_3	10^[illegible]	17	OX	10^[illegible]	27	EDTA	10^[illegible]
8	S^{2-}	10^[illegible]	18	SAL	10^[illegible]	28	DCTA	10^[illegible]
9	PO_4^{3-}	10^[illegible]	19	TART	10^[illegible]	29	CYST	10^[illegible]
10	$P_2O_7^{4-}$	10^[illegible]	20	EN	10^[illegible]	30	NOC	10^[illegible]
						31	PHTH	10^[illegible]

[a] The equilibrium computation for this system involves 738 complexes and 83 possible solids. There is one gas phase component, CO_2. Pressure, temperature, ionic strength, pH, and oxidation reduction state are all assumed to be constant. Fixed pH = 8, fixed $p_{CO_2} = 10^{-3.5}$ atm, ionic strength ~ 0.5*M*

AC = acetate
ACAC = acetylacetone
CIT = citrate
OX = oxalate
SAL = salicylate
TART = tartrate
EN = ethylenediamine
DIP = dipyridyl
SUSAL = sulfosalicylate

GLY = glycine
GLUT = glutamate
PIC = picolinate
NTA = nitrilotriacetate
EDTA = ethylenediaminetetraacetate
DCTA = 1,2-diaminocyclohexane-tetraacetate
CYST = cysteine
NOC = nocardamine (desferri-ferrioxamine)
PHTH = phthalate

Iteration no.		
0	First guesses: all free concentrations = 10^{-9} *M* Chosen set of solids: S_{1-1}, S_{1-9}, S_{3-1}, S_{4-21}, S_{10-9}, S_{12-17}, S_{13-1}, S_{14-8}, S_{17-21}, S_{20-17}, S_{20-21}, S_{21-1} [CO_2 (g)]	
31	S_{13-1}	dissolves
39	S_{1-4}	precipitates
42	S_{14-20}	precipitates
45	S_{1-2}	precipitates
49	S_{3-1}	dissolves
53	S_{8-1}	precipitates
56	Found set of solid: S_{1-1}, S_{1-4}, S_{1-9}, S_{2-5}, S_{4-21}, S_{8-1}, S_{10-9}, S_{12-17}, S_{14-8}, S_{17-21}, S_{19-11}, S_{20-17}, S_{20-21}, S_{21-1} [CO_2 (g)] See solution Table IV	

Figure 11. Successive modifications of sets of solids in a 20-metal, 31-ligand model system

After 56 iterations an equilibrium set of 13 solids [+CO_2 (g)] is found

Appendix

DERIVATIVES OF THE MOLE BALANCE EQUATIONS

$$\text{Let } YM_i = [M_i] + \sum_{j,k} \alpha[C_{ijk}] - TOTM_i \text{ (= 0 from Eq. 3)}$$

$$YL_j = [L_j] + \sum_{i,k} \beta[C_{ijk}] - TOTL_j \text{ (= 0 from Eq. 3)}$$

$$YH = [H] - [OH] + \sum_{\substack{\text{last row}\\ j,k}} \alpha[C_{ijk}] -$$

$$\sum_{\substack{\text{last column}\\ i,k}} \beta[C_{ijk}] + \sum_{i,j,k} \gamma[C_{ijk}] - TOTH \text{ (= 0 from Eq. 4)}$$

By use of Equation 1: $[C_{ijk}] = K_{ijk}[M_i]^{\alpha}[L_j]^{\beta}[H]^{\gamma}$ it follows:

$$\frac{\partial YM_i}{\partial [M_k]} = 0 \text{ for } i \neq k$$

$$\frac{\partial YL_j}{\partial [L_k]} = 0 \text{ for } j \neq k$$

$$\frac{\partial YM_i}{\partial [M_i]} = 1 + \sum_{j,k} \alpha^2[C_{ijk}]/[M_i]$$

$$\frac{\partial YL_j}{\partial [L_j]} = 1 + \sum_{i,k} \beta^2[C_{ijk}]/[L_j]$$

$$\frac{\partial YM_i}{\partial [L_j]} = \sum_{k} \alpha\beta[C_{ijk}]/[L_j]$$

Table IV. Equilibrium Composition of the Aqueous Solution Phase for the Model System

Concentrations of metals, ligands, and complexes are given as negative logarithms. The values for the complexes are the sums of the complexes of a particular metal and ligand. (s) indicates that a solid exists at equilibrium,[a] and (g) indicates the gas phase component (CO_2)

Metals	Total concn	Free concn	CO_3^{2-}	SO_4^{2-}	Cl^-	F^-	Br^-	I^-	NH_3	S^{2-}	PO_4^{3-}	$P_2O_7^{4-}$	$P_3O_{10}^{5-}$	$SiO_2(OH)_2^{2-}$	$S_2O_3^{2-}$	AC
Ligands Total concn			0.5	1.5	0.3	2.0	3.0	6.0	6.0	8.0	3.0	7.0	8.0	0.01	7.0	6.3
Free concn			4.50	2.00	0.30	3.65	3.00	6.05	7.23	32.55	11.10	10.41	12.4	10.60	15.75	6.37
Ca^{2+}	1.0	2.50	4.33(s)	3.30		5.65(s)			9.93		9.00(s)	7.93	9.51		17.45	8.37
Mg^{2+}	1.2	1.28	3.17	1.99		3.63			8.31		7.98	7.12	8.02		16.33	7.15
Sr^{2+}	2.7	4.20		(s)							10.88	11.33	12.58		19.04	10.17
K^+	2.0	2.01		3.52								10.15	11.65		17.35	
Na^+	0.3	0.31	4.11	2.11								8.04	9.94		15.95	
Fe^{3+}	1.0	18.90		18.48	18.39	16.83	22.20	23.65			20.00	23.13		15.50	32.65	21.87
Fe^{2+}	8.0	8.95		9.75	8.85				14.78							12.12
Mn^{2+}	7.0	7.57	9.07	8.37	7.17				14.00		12.47	14.41			22.52	13.44
Cu^{2+}	3.5	7.90	7.59(s)	8.70	8.50	10.75	10.40		9.23		13.40	11.63	13.03			12.57
Ba^{2+}	3.0	8.00		(s)								13.83	14.13		22.34	13.97
Cd^{2+}	6.0	8.28	10.78	9.09	6.00	11.43	9.68	11.93	12.91		17.38	11.52	12.52		21.23	13.65
Zn^{2+}	3.0	6.80		7.60	6.27	9.65	10.40		11.73			8.51	12.34	(s)	21.35	11.87
Ni^{2+}	6.0	6.34		7.15	6.84	9.39	9.44		10.77			10.98			21.09	12.01
Hg^{2+}	6.0	20.05		20.71	6.06	22.70	8.65	8.35	17.00	32.15(s)		18.79			7.00	
Pb^{2+}	7.0	9.19		9.69	7.01		11.09	13.97				24.76			19.83	13.66
Co^{2+}	7.0	7.25		7.85	7.75		10.35		12.48				13.08		22.10	12.52
Co^{3+}	4.0	26.70				25.78			26.51							
Ag^+	7.0	14.75		16.25	9.87		13.35	7.00	18.58	30.50					22.20	20.72
Cr^{3+}	4.0	13.20		12.20		12.29										
Al^{3+}	0.01	15.30		15.86		10.81								(s)		
H^+		8.00	2.90(g)	8.20		8.75			6.03	27.92	7.28	9.93	12.51	4.48	22.45	9.77

Metals	ACAC	CIT	OX	SAL	TART	EN	DIP	SUSAL	GLY	GLUT	PIC	NTA	EDTA	DCTA	CYST	NOC	PHTH	OH
Ligands Total concn	7.0	6.0	5.7	6.3	6.0	7.0	7.0	7.0	6.0	6.0	6.3	7.0	7.3	7.3	8.0	8.0	7.3	
Free concn	8.96	16.32	6.94	11.80	6.30	9.83	7.97	10.60	7.83	7.75	7.45	12.28	19.59	20.88	16.13	21.65	7.35	5.70
Ca^{2+}		7.32	6.44		7.10				9.73	8.85	8.15	8.38	11.39	10.88		12.85	8.25	7.30
Mg^{2+}	7.04	6.81	5.82		6.38	10.71	8.76		8.12	7.13	6.54	8.16	14.18	11.86		8.94		4.88
Sr^{2+}		9.72	9.73						11.43	10.54	9.95	11.47	15.19	15.07		13.95		9.30
K^+																		
Na^+												10.98	18.20					
Fe^{3+}	18.40	10.22	17.75	13.95				14.69	16.73	14.55		10.60	12.51	10.44	19.95	8.05		8.30(s)
Fe^{2+}	13.21	9.77		14.15		14.48	12.52	13.65	12.88	12.60	11.51	12.42	14.24	11.63	14.07			8.15
Mn^{2+}	12.72	12.49	11.80	13.47		14.70	13.04	12.97	13.40	12.52	11.44	12.45	13.16	11.65	20.09	17.31		10.07
Cu^{2+}	9.06	6.22	10.33	9.10	11.00	7.15	7.77	9.00	7.47	8.22	7.24	7.43	8.69	7.48		14.90	12.15	8.20
Ba^{2+}		29.92	13.72	19.49	12.79				15.43	14.44	13.76	15.57	19.79	20.85			13.85	13.30
Cd^{2+}	13.84	12.08	12.32	14.49	11.78	12.61	11.76	14.19	11.72	11.63	11.15	10.46	11.38	9.97		21.06	13.14	9.68
Zn^{2+}	11.16	11.72	10.04	11.70	10.70	10.93	9.37	11.30	9.37	9.55	8.96	8.58	9.89	8.98	13.02	16.25	11.95	8.69
Ni^{2+}	9.80	8.35	9.18	11.14		8.47	7.18	10.55	8.37	8.59	7.00	7.32	7.33	7.82	19.79	15.79	11.59	7.44
Hg^{2+}						16.32			16.19		19.25	16.73	17.78	16.63	8.30			
Pb^{2+}	13.95	12.26			11.69		14.16		11.92		12.05	9.67	10.78	10.37	13.01		13.14	
Co^{2+}	11.21	26.77	10.69	12.25	11.45	11.17	9.52	11.85	10.38	10.40	9.01	9.03	10.54	9.23	14.27	17.09	17.95	8.05
Co^{3+}						9.29							10.29					(s)
Ag^+		30.72	19.29			19.88	23.89		19.28		18.82		27.04					18.55
Cr^{3+}			14.64					14.20					8.84					6.30(s)
Al^{3+}	16.14	6.72	18.17	13.10				12.91				12.78	16.39	17.80				7.50(s)
H^+	8.16	8.32	10.94	6.30	10.20	7.86		7.00	6.03	6.05	10.06	10.48	17.29	18.07	13.08	17.65	10.25	

[a] −log (moles solid per liter of solution): $CaCO_3$, 1.05; CaF_2, 2.32; $Ca_5(PO_4)_3OH$, 3.48; $SrSO_4$, 2.72; $Fe(OH)_3$, 1.00; $Cu_2CO_3(OH)_2$, 3.80; $BaSO_4$, 3.00; $ZnSiO_3$, 3.00, HgS, 8.00; $Co(OH)_2$, 4.00; $Cr(OH)_3$, 4.00; $Al_2Si_2O_5(OH)_4$, 0.31; $Al(OH)_3$, 2.99

$$\frac{\partial YL_j}{\partial [M_i]} = \sum_i \alpha\beta[C_{ijk}]/[M_i]$$

$$\frac{\partial YM_i}{\partial [H]} = \sum_{j,k} \alpha\gamma[C_{ijk}]/[H] - \sum_{\substack{\text{last column}\\ k}} \alpha\beta[C_{ijk}]/[H]$$

$$\frac{\partial YH}{\partial [M_i]} = \sum_{j,k} \alpha\gamma[C_{ijk}]/[M_i] - \sum_{\substack{\text{last column}\\ k}} \alpha\beta[C_{ijk}]/[M_i]$$

$$\frac{\partial YL_j}{\partial [H]} = \sum_{i,k} \beta\gamma[C_{ijk}]/[H] + \sum_{\substack{\text{last row}\\ i,\ k}} \alpha\beta[C_{ijk}]/[H]$$

$$\frac{\partial YH}{\partial [L_j]} = \sum_{i,k} \beta\gamma[C_{ijk}]/[L_j] + \sum_{\substack{\text{last row}\\ k}} \alpha\beta[C_{ijk}]/[L_j]$$

$$\frac{\partial YH}{\partial [H]} = 1 + [OH]/[H] + \sum_{i,j,k} \gamma^2[C_{ijk}]/[H] + \sum_{\substack{\text{last row}\\ j,k}} \alpha^2[C_{ijk}]/[H] + \sum_{\substack{\text{last column}\\ i,k}} \beta^2[C_{ijk}]/[H]$$

Whenever a solid S_{ij} precipitates, a new secondary variable is defined according to Equation 7; say

$$[M_i] = \mu[L_j]^{\nu}[H]^{\nu'}$$

Then the derivatives are modified in the following way:

$$\text{new}\ \frac{\partial YM \text{ or } \partial YL}{\partial [L_j]} = \text{old}\ \frac{\partial YM \text{ or } \partial YL}{\partial [L_j]} + \nu \frac{[M_i]}{[L_j]} \frac{\partial YM \text{ or } \partial YL}{\partial [M_i]}$$

$$\text{new}\ \frac{\partial YM \text{ or } \partial YL}{\partial [H]} = \text{old}\ \frac{\partial YM \text{ or } \partial YL}{\partial [H]} + \nu' \frac{[M_i]}{[H]} \frac{\partial YM \text{ or } \partial YL}{\partial [M_i]}$$

Furthermore, since the equations are modified according to Equation 8; say

$$\text{new } YL_j = \text{old } YL_j + \nu \cdot YM_i$$

$$\text{new } YH = \text{old } YH + \nu' \cdot YM_i$$

(YM_i will be discarded in the rest of the computation.)

We have to modify the derivatives further:

$$\text{new}\ \frac{\partial YL_j}{\partial [M] \text{ or } \partial [L]} = \text{old}\ \frac{\partial YL_j}{\partial [M] \text{ or } \partial [L]} + \nu \cdot \frac{\partial YM_i}{\partial [M] \text{ or } \partial [L]}$$

$$\text{new}\ \frac{\partial YH}{\partial [M] \text{ or } \partial [L]} = \text{old}\ \frac{\partial YH}{\partial [M] \text{ or } \partial [L]} + \nu' \frac{\partial YM_i}{\partial [M] \text{ or } \partial [L]}$$

It should be noted that the order in which those modifications are made is not indifferent for $\frac{\partial YL_j}{\partial [L_j]}$ or $\frac{\partial YH}{\partial [H]}$; the order shown here is the correct one.

Acknowledgment

This work was supported in part by a grant from the Gulf Oil Corp. We thank Russell E. McDuff for help in making the computations.

Nomenclature

C_{ijk}	= complex k formed by reaction of M_i with L_j
H	= hydrogen ion
J	= Jacobian matrix of the system
K_{ij}	= dissociation constant for the solid S_{ij} (corrected for ionic strength)
K_w	= ion product of water
L_j	= ligand j
M_i	= metal i
OH	= hydroxide ion
$p[\ ]$	= negative logarithms of the concentrations
S_{ij}	= solid formed by reaction of M_i with L_j
$TOTM_i$, $TOTL_j$	= analytical (total) concentrations of metals and ligands in all phases of the system, respectively
$[Y(X) = 0]$	= general system of equations to be solved

GREEK LETTERS

α_{ijk}	= stoichiometric coefficient of M_i in C_{ijk}
β_{ijk}	= stoichiometric coefficient of L_j in C_{ijk}
γ_{ijk}	= stoichiometric coefficient of H or OH in C_{ijk}
δ_{ij}	= stoichiometric coefficient of M_i in S_{ij}
η_{ij}	= stoichiometric coefficient of L_j in S_{ij}
λ_{ij}	= stoichiometric coefficient of H or OH in S_{ij}
μ, ν, ν'	= constants defined in text

SYMBOLS

[ ]	= concentrations
$[\ ]_T$	= number of moles of a substance used to make up the system, per liter of solution
$\equiv$	defines the formulas (distinct from =)

Literature Cited

Brinkley, S. R., *J. Chem. Phys.*, 15, 107 (1947).
Denbigh, K. G., "The Principles of Chemical Equilibrium," Cambridge Univ. Press, Cambridge, England, 1966.
Garrels, R. M., Christ, C. L., "Solutions, Minerals, and Equilibria," Harper, New York, N.Y., 1965.
Ingri, N., Kakolowicz, W., Sillén, L. G., Warnqvist, B., *Talanta*, 14, 1261 (1967).
Isaacson, E., Keller, H. B., "Analysis of Numerical Methods," Wiley, New York, N.Y., 1966.
Ringbom, A., "Complexation in Analytical Chemistry," Wiley-Interscience, New York, N.Y., 1963.
Shapiro, N. Z., "A Generalized Technique for Eliminating Species in Complex Chemical Equilibrium Calculations," Rand Corp. Memo 4205-PR, AD-605 316 (1964).
Sillén, L. G., "Oceanography," in "Physical Chemistry of Sea Water," M. Sears, Ed., American Association for the Advancement of Science, Washington, D.C., 1961.
Sillén, L. G., Martell, A. E., *Chem. Soc. Spec. Publ.* 17 (1964).
Stumm, W., Morgan, J. J., "Aquatic Chemistry," Wiley science, New York, N.Y., 1970.
White, W. B., Johnson, S. M., Dantzig, G. B., *J. Chem. Phys.*, 28, 751 (1958).
Zeleznik, F. J., Gordon, S., *Ind. Eng. Chem.*, 60, 27 (1968).

Received for review Nov. 25, 1970. Accepted March 14, 1971.

Figure 12 will appear following these pages in the microfilm edition of this volume of the Journal. Single copies may be obtained from the Business Operations Office, Books and Journals Division, American Chemical Society, 1155 Sixteenth St., N.W., Washington, D.C. 20036, by referring to author, title of article, volume, and page number. Remit by check or money order $3.00 for photocopy or $2.00 for microfiche.

(13) Elliott, D. E., "Keynote Address: Exploiting Fluidized Bed Combustion," Proc. 2nd Intern. Conf. Fluidized Bed Combustion, U.S. EPA, Pub. No. AP-109, 1970.
(14) Zielke, C. W., Lebowitz, H. E., Struck, R. T., Gorin, E., "Sulfur Removal During Combustion of Solid Fuels In a Fluidized Bed of Dolomite," *J. Air Pollut. Contr. Assoc.*, **20** (3), 164-9 (1970).
(15) Kunii, D., Levenspiel, O., "Fluidization Engineering," Wiley & Sons, Inc., New York, N.Y., 1969.
(16) Avedesian, M. M., "Combustion of Carbon Particles in a Fluidized Bed," PhD Thesis, University of Cambridge, England, 1972.
(17) Jonke, A. A., Carls, E. L., Vogel, G. J., Anastasia, L. J., Jarry, R. L., Haas, M., "Reducing Pollution from Fossil Fuel Combustion," *Instru. Contr. Systems*, **44** (7), 95-8 (1971).
(18) Jonke, A. A., "Fluidized-Bed Combustion Related to Air Pollution," *Eleventh Ann. Indus. Coal Conf. Lexington, Ky.*, April 12-13, 1973.
(19) Jonke, A. A., Vogel, G. J., Anastasia, L. J., Jarry, R. L., "Work Plan for Continuation of the Project 'Reduction of Atmospheric Pollution by the Application of Fluidized Bed Combustion'," Nat. Tech. Inform. Serv. Pub. No. ANL ES CEN-1003, April 1971.
(20) Hammons, G. A., Skopp, A., "NO, Formation and Control in Fluidized Bed Coal Combustion Processes," ASME Pub., No. 71-WA/APC-3, Am. Soc. Mech. Eng., New York, N.Y., 1971.
(21) Parks, D. J., "Formation of Nitric Oxide in Fluidized Bed Combustion," PhD Thesis, University of Minnesota, Minneapolis, Minn., 1973.
(22) Geldart, D., Kelsey, J. R., "The Influence of the Gas Distributor on Bed Expansion, Bubble Size, and Bubble Frequency in Fluidized Beds," Institution of Chemical Engineers Symp. Ser., No. 30, London, pp. 114-23, 1968.
(23) England, C., Houseman, J., Teixeira, D. P., "Sampling Nitric Oxide from Combustion Gases," *Combust. Flame*, **20** (3), 439-42 (June 1973).

Received for review September 12, 1974. Accepted April 16, 1975. Work supported by Northern States Power Co.

Fate of Trace Metals in Los Angeles County Wastewater Discharge

François M. M. Morel,* John C. Westall,[1] Charles R. O'Melia,[2] James J. Morgan[3]

Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics, Department of Civil Engineering, Massachusetts Institute of Technology, Cambridge, Mass. 02139

■ A chemical equilibrium model of the Los Angeles County sewage is presented which accounts for the chemical speciation of trace metals. Many metals are found in very insoluble sulfide (Zn, Hg, Ag, Cu, Cd, Pb) or oxide (Cr, Fe) forms, while some (Ni, Co, Mn) are relatively soluble. A study of the oxidation and dilution of the sewage by seawater demonstrates that most metals tend to be solubilized upon disposal in the ocean and that unmeasurable increments in the natural metal concentrations should result in the farfield. It is argued that the sewage particulate is not mobilized in the vicinity of the outfall and that the nearby sediments are a mixture of naturally occurring sediments and sewage particulate. About 0.5% of the sewage particulate—and its metal content—can be accounted for in the reduced area.

The possible short- and long-range effects of the disposal of trace metals in the coastal environment are a matter of growing concern. Rational management of such practices is made difficult by lack of understanding of the factors that regulate the fate of metals in the ocean. This report represents an effort to confront our understanding of the chemistry of wastewaters discharged into seawater with experimental data on the concentrations of various metals in sediments adjacent to a major outfall system. The first section of this report outlines some background information on the Joint Water Pollution Control Project (JWPCP) of the Los Angeles County Sanitation District chosen for this study. In the second section, chemical equilibrium models of sewage and sewage-seawater mixtures are employed to examine the possible speciation of trace metals that are discharged. The fate of metals deposited in the area adjacent to the outfalls is discussed in the third section.

[1] Present address, Department of Chemistry, Massachusetts Institute of Technology, Cambridge, Mass.
[2] Present address, Department of Environmental Science and Engineering, School of Public Health, University of North Carolina, Chapel Hill, N.C.
[3] Present address, W. M. Keck Laboratory, California Institute of Technology, Pasadena, Calif.

JWPCP Outfall System

The JWPCP outfall system is well suited for a study on the fate of metallic pollutants for several reasons:

1. The quantities of wastewater are very large (~370 mgd) and they consist of both domestic and industrial sewage containing high metal concentrations, so that the effects are most dramatic and easily measured. Table I gives the average concentrations in the treated effluent of 11 metals selected for this study. These concentrations are compared to the concentrations in the Southern California coastal waters and the ratios are indicative of possible magnitudes of effects. Chromium and lead are comparatively the most concentrated metals in the sewage with ratios $C_{sewage}/C_{seawater}$ of about 4000 and 6000, respectively. The last three columns of Table I give mass emission rates for the metals studied: JWPCP outfalls are major contributors of metals to the Bight. For several metals they account for more than a quarter of the total input estimated as the sum of sewers, rivers, rainfall, aerial fallout, vessel dumping, and various discrete sources.

2. The JWPCP sewage treatment is fairly typical of commonly used primary treatment techniques. The sedimented sludge is digested anaerobically, centrifuged, and the centrate is re-mixed with the primary effluent, contributing much of its particulate—and metal—load.

3. The two main JWPCP submarine outfalls—a 90-in. "Y" outfall and a 120-in. "dog leg" outfall, both discharging at a depth of 60 meters at the edge of the continental shelf—have been designed for specific hydraulic performance; the rise of the plume as well as the dilution of sewage by seawater have been especially well studied (*1*).

4. Monitoring programs of the sewage composition have been carried out at the JWPCP plant (*2*), and a study of the metal concentrations in the nearby sediments has been completed (*3*) so that an experimental data base is available.

Equilibrium Models

To discuss the behavior of sewage upon dilution and oxidation, it is first necessary to understand the redox level and speciation of metals in the sewage itself. For this purpose, a chemical equilibrium model (*4*, *5*) of the inorganic species in sewage has been used; to this basic inorganic model a set of representative organic ligands and an adsorbing surface have been added, and the effects of both on metal speciation will be seen.

The input to the inorganic model includes the analytical concentrations of trace metals found in sewage, the analytical concentrations of major metals and ligands, and the measured pH of 7.7 (Table II, column 1). Because the redox level (pε) is not an experimentally measured quantity, we have attempted to find a range of pε where the calculated partition of metals between the particulate and soluble phases matches the experimentally determined filterable/nonfilterable fractionation. In the JWPCP sewage, the pε is probably best described as a function of the bacterially mediated reduction of sulfate,

$$SO_4^{2-} + 8H^+ + 8e^- = S^{2-} + 4H_2O$$

coupled with the oxidation of organic carbon. The activity of SO_4^{2-} is much greater than that of S^{2-} and effectively constant: Thus, the free sulfide activity—hence the solubility of metal sulfides—is a valuable indicator of the redox level of sewage. [It could be argued here that metals are rendered insoluble by precipitation with complex organic matter; however, the paucity of data on such forms does not allow their inclusion in the model. In any case, equilibrium between metals and sulfide—with the resulting precipitation of very insoluble metal sulfides—ought to be a good approximation for sewage which has been digested (*6*).]

Trace metal speciation as a function of the negative logarithm of the total sulfide concentration in the sewage ($pTOTS^{2-}$) is presented in Figure 1. It is shown that over the range $pTOTS^{2-}$ = 3.7-5.5, the activity of free sulfide ion is controlled successively by the solubilities of iron, zinc, and copper sulfides; accordingly the pε as computed from the sulfate/sulfide equilibrium varies over three plateaus at pε −4.0, −3.47, and 2.94. (For future study it should be noted that important analytical information about sewage composition is given either by a precise measure of the free sulfide concentration or by the relative analytical concentrations of copper, zinc, iron, and sulfide. Routine analytical techniques that are now in use do not really yield either.)

Experimental data (*2*, *3*) show the majority of trace metals to be in the nonfilterable fraction of sewage, with the exception of nickel, cobalt, and manganese found in approximately equal concentrations in the filterable and nonfilterable fractions. ("Nonfilterable" is operationally defined as the solid retained by a 0.45 μM Millipore filter. This is taken as an approximation of the total suspended matter.) In attempting to match these data to a region in Figure 1, one finds the transition range between pε −4.0 and pε −3.47 to be in reasonable agreement: Most metals are in an insoluble sulfide (Zn, Hg, Ag, Cu, Cd, Pb) or oxide

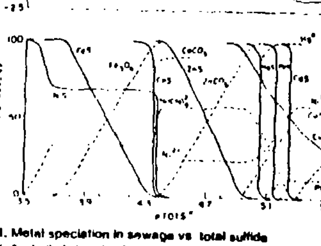


Figure 1. Metal speciation in sewage vs. total sulfide
Input is similar to that given for the inorganic model in Table II, except that the total sulfide is imposed and the pε is calculated from the SO_4^{2-}/S^{2-} equilibrium

Table I. Trace Metals in JWPCP Sewage Outfall

	Concentrations, μg/l., estimate			Mass emission rates, T/y, to So. Calif. Bight		
	JWPCP[a] sewage	So. Calif.[b] seawater	Sewage–seawater ratio	JWPCP[c]	Total[d]	JWPCP/total ratio
Fe	9900	10.0	1000	5300	20,000	0.27
Zn	2400	10.0	250	1300	2,400	0.54
Cr	860	0.2	4000	460	700	0.66
Cu	560	3.0	200	300	1,000	0.30
Pb	250	0.04	6000	140	550	0.25
Ni	240	6.0	40	130	400	0.33
Mn	130	2.0	70	70	350	0.20
Cd	30	0.1	300	16	65	0.25
Ag	20	0.3	70	11	20	0.55
Co	10	0.2	50	5	25	0.20
Hg	1	0.03	30	0.5	10	0.05

[a] Data from SCCWRP (*2*) 1971 averages. [b] Selected from SCCW tabulation (*2*) of literature data. These data show great variability. This is particularly true for the less abundant metals, the estimates of which are probably too high. [c] Mass emission rates obtained by multiplying column 1 by 540 × 10⁹ l./yr (1971 flow). [d] Sum of wastewater discharges, surface runoff, vessel coating, ocean dumping, rainfall, and aerial fallout as estimated by critical examination of SCCWRP data (*2*).

Table II. Equilibrium Models of JWPCP Sewage

−Log total Concn	Inorganic model,[a] %	Addition of organics,[a,b] %	Addition of adsorbing surface,[a,b,c] %
Fe, 3.7	Fe_3O_4(s), 100	Fe_3O_4(s), 100	Fe_3O_4(s), 100
Cr, 4.8	$Cr(OH)_3$(s), 97 $Cr(OH)_4^-$, 3	$Cr(OH)_3$(s), 97 $Cr(OH)_4^-$, 3	$Cr(OH)_3$(s), 52 $Cr(OH)_4^-$, 3 ADS, 45
Cu, 5.0	CuS(s), 100	CuS(s), 100	CuS(s), 100
Cd, 6.5	CdS(s), 100	CdS(s), 100	CdS(s), 100
Pb, 6.0	PbS(s), 100	PbS(s), 100	PbS(s), 100
Zn, 4.5	ZnS(s), 100	ZnS(s), 99	ZnS(s), 99
Ag, 6.7	Ag_2S(s), 100	Ag_2S(s), 100	Ag_2S(s), 100
Hg, 8.3	HgS(s), 100	HgS(s), 100	HgS(s), 100
Ni, 5.4	NiS(s), 42 Ni^{2+}, 2 $Ni(CN)_4^{2-}$, 56	NiS(s), 22 Ni^{2+}, 2 $Ni(CN)_4^{2-}$, 56 GLY, 10 GLU, 10	NiS(s), 14 Ni^{2+}, 2 $Ni(CN)_4^{2-}$, 56 GLY, 10 GLU, 10 ADS, 8
Co, 6.8	CoS(s), 97 Co^{2+}, 2	CoS(s), 95 Co^{2+}, 2 GLU, 2	CoS(s), 93 Co^{2+}, 2 GLU, 2 ADS, 2
Mn, 5.6	Mn^{2+}, 50 $MnHCO_3^+$, 24 $MnSO_4$, 19 $MnCl^+$, 6	Mn^{2+}, 50 $MnHCO_3^+$, 24 $MnSO_4$, 19 $MnCl^+$, 6	Mn^{2+}, 45 $MnHCO_3^+$, 21 $MnSO_4$, 17 $MnCl^+$, 6 ADS, 9

[a] Other inputs to the model (*2*): pH = 7.7, pCa = 2.75, pMg = 3.0, pBa = 5.0, pAl = 4.5, pCO_3 = 2.0, pSO_4 = 2.3, pCl = 1.8, pF = 4.0, pNH_3 = 2.2, pPO_4 = 3.3, pCN = 5.0, Ionic strength = 0.01, t = 25°C. [b] Organic ligands added: pAcetate = 3.3, pGlycine = 3.8, pTartrate = 3.6, pGlutamate = 3.7, pSalicylate = 3.8, pPhthalate = 3.9. [c] Adsorbing surface: 10 m² l.⁻¹, constant potential. The computation is performed according to the James and Healy model (*6*) which considers coulombic, solvation, and specific chemical energy interactions. The chemical energy term is essentially a fitting parameter and has been chosen arbitrarily in the model to represent high chemical affinity of the adsorbing surface for all metals (about 10 kcal/mol).

(Cr, Fe) form; the sulfides of cobalt and nickel dissolve in this region, cobalt being replaced by a more soluble $CoCO_3$, and nickel being rendered soluble. Significant amounts of chromium, cobalt, nickel, and manganese may be adsorbed onto the particulate fraction, as will be discussed later.

A better agreement between model and data could certainly be achieved through minor variations in pH, pε, or equilibrium constants. But in any case, this basic inorganic model allows us to choose a range of pε from which computation of dilution and oxidation effects can begin. Table II, column 2, presents a summary of metal species in the inorganic model of JWPCP sewage, computed at an intermediate pε in this range, pε −3.8. As stated above, most metals are in insoluble forms; the sulfides of cobalt and nickel are partially dissolved, and manganese is in various soluble forms.

To make the model more realistic, organic ligands should be included. However, since very little analytical information concerning organics in the JWPCP sewage is available, we have chosen to select a set of organics that represent various functional groups and complexing behaviors consistent with the results of Manka et al. (7) for the organic fraction of various wastewaters. Acetate, tartrate, glycine, salicylate, glutamate, and phthalate were added, each at an equivalent carbon concentration of 10^{-3}M (6×10^{-3}M carbon is an upper limit on the experimental dissolved organic carbon in JWPCP sewage). The principal results of this computation are shown in the third column of Table II. By choosing an upper limit on the dissolved organic carbon, it is hoped that the probable effects of organic ligands will be overestimated; nonetheless the addition of organics has little effect on the results of the computation. The only metals that show significant binding with the organic ligands are cobalt and nickel; the reactivity of most other metals is limited due to the extreme insolubility of the solid forms.

The last column of Table II shows the results of a model similar to that of column 3 but including an adsorbing surface in addition. The surface was made to possess characteristics similar to those of metal oxides, and the computations of adsorption were made according to the model of James and Healy (8). Only four metals were found to adsorb markedly: chromium cobalt, nickel, and manganese. That the particulate fraction of manganese in sewage (about 20–50%) is indeed adsorbed, can be experimentally corroborated by mixing sewage with seawater and readily "solubilizing" the manganese. In contrast, no such desorption effect can be shown for chromium, nickel, or cobalt.

Overall an equilibrium model for sewage can be made to match closely the existing experimental data, but such effort is not warranted until more detailed analytical data are obtained. Since organics are likely to be less important in the plume where they start decomposing, and since the metals studied should readily desorb in seawater, the inorganic model will serve as our basic tool to investigate the chemical processes that should govern the fate of sewage metals entering the ocean.

Figure 2 presents in concise form a summary of results from a large number of computations for various mixtures of sewage and seawater at various redox potentials. The pH imposed at each dilution was calculated from the carbonate alkalinity and total carbonate of the corresponding sewage-seawater mixture. The ionic strength was approximated by the appropriate dilution of sewage (I = 0.01) with seawater (I = 0.5). The lines in Figure 2 demark the domain of pε and dilution in which various insoluble forms of the trace metals are stable. A detailed description of soluble speciation has been omitted to preserve clarity in the figure.

Figure 2 shows that, in general, oxidation has a much greater effect on the solubilization of metals than dilution. However, there are two effects of dilution which should be mentioned: (1) at low dilution and moderate oxidation the carbonates of zinc, lead, and cobalt precipitate because of the high concentration of carbonate in sewage, and the hydroxide of chromium(III) precipitates because of the relatively high concentration of chromium. (2) At high dilution, the chloride from seawater can bind significant quantities of metals, and for the well-oxidized, well-diluted system, the chloride complexes of Ag, Hg, Pb, Cd, and Mn represent the major species of these metals.

The significant effect of oxidation on most metals (Fe, Zn, Cu, Co, Ni, Pb, Cd, Hg, Ag) is the dissolution of the sulfide solid; in addition, a more complicated behavior for Cu and Hg is observed. A fraction of the cupric sulfide is oxidized first to a $Cu(CN)_2^-$ (cuprous) complex, and after exhaustion of available CN^-, the formation of metallic copper is seen. Upon further oxidation, various soluble complexes of the cupric ion predominate. Mercury shows a similar pattern of oxidation from HgS to metallic liquid mercury and finally to the mercuric ion. At higher pε levels are the oxidation of Cr(III) to Cr(VI), the transition of Fe_3O_4 to FeOOH, and the formation of insoluble manganese and cobalt oxides.

As sewage enters the ocean environment and is simultaneously diluted and oxidized, the chemical equilibrium is presented on Figure 2 by a point moving to the right and upward. No kinetic information is contained in this figure such that, unless the reactions are fast, it does not describe the composition of the system but, rather, the driving force at each point. Typically, in the JWPCP outfalls, a dilution of 50 is obtained immediately in the plume, and little or no oxidation takes place at that time. For the soluble fraction or the light particles transported far from the outfall, higher dilutions are slowly obtained at the same time that oxidation proceeds. A final situation is reached, represented by the top right-hand corner of Figure 2, where most of the metals are solubilized in the free form or various chloride, carbonate, or hydroxide complexes.

This solubilization of metals increases their retention time in the water column and ensures a very high dilution. Hence, in the farfield the concentrations of metals should not be increased measurably over the natural seawater background. The situation is drastically different in the immediate vicinity of the outfall as will now be discussed.

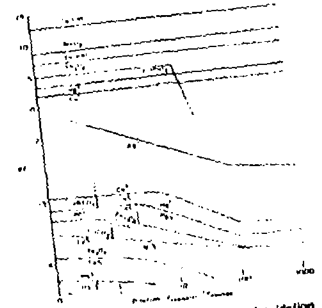


Figure 2. Metal solids as function of dilution and oxidation
Composition of diluting seawater: pH = 8.2, pCa = 2.0, pMg = 1.2, pBa = 6.7, pFe = 6.8, pZn = 6.8, pCr = 8.4, pCu = 7.3, pPb = 9.7, pNi = 7.0, pMn = 7.4, pCd = 9.0, pAg = 8.5, pCo = 8.3, pHg = 9.8, pAl = 7.0, pCO_3 = 2.6, pSO_4 = 1.5, pCl = 3.6, pF = 4.2, pNH_3 = 6.0, pPO_4 = 5.7, pCN = 9.0. Ionic strength = 0.5

Table III. % Concentrations Relative to Zinc

	Sewage		Top 4 cm of sediments	
	Total (SCCWRP)	Particulate (Galloway)	B.21	B.20
Zn	100	100	100	100
Ag	0.83	0.78	0.89	0.93
Cr	36	41	41	41
Cu	23	27	28	29
Pb	10	14	19	20
Cd	1.2	1.6	2.7	3.1
Co	0.41	0.20	0.22	0.32
Ni	10	5.3	1.3	1.6
Mn	5.4	3.6	15	14

Nearfield Deposition: The Question of Mobilization

It is well documented (2, 9) that, in the normally oxic ocean floor off Palos Verdes, there exists an area of reduced surface sediments about 10 miles long and one mile wide on a NW-SE axis around the county outfall system. Since enough organic carbon must be brought continuously to the ocean floor to maintain anaerobic conditions in this region, a relatively high sedimentation of sewage particulates is implied. We shall examine in this section what metals are likely to be mobilized in the reduced sediments, how this is reflected in the changes of relative concentrations from sewage particulate to surface sediments, and whether metal concentrations in the reduced area are consistent with estimated sedimentation rates.

The system composed of the reduced surface sediments and the associated anoxic seawater is roughly equivalent to a very low dilution of sewage by seawater: After initial dilution in the plume, an effective reconcentration takes place for those particulates that settle near the outfall. Since, in addition, bacterial activity must maintain the redox level of these sediments at about the same pε as that of primary effluent, the bottom left corner of Figure 2 represents the possible set of solid species to be expected in this region. Of the metals under study, only nickel, possibly cobalt, and, of course, manganese are likely to be dissolved in the reduced sediments.

Given an average current velocity of 0.1 m sec^{-1}, suspended particles will be transported outside of the area of reduced sediments within 24 hr. Our laboratory experiments have demonstrated no significant mobilization of metals, except nickel and manganese, over a day, in aerated mixtures of sewage and seawater. It seems therefore justified to assume that no significant mobilization in the water column or in the sediments will occur for iron, zinc, silver, chromium, copper, lead, cadmium, and mercury contained in the particles that reach the reduced sediments. This will be referred to as the "no-mobilization hypothesis."

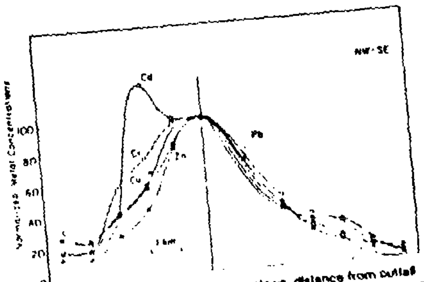


Figure 3. Total concentration in sediments vs. distance from outfall
Cobalt, nickel and manganese have been omitted as irrelevant. Data for silver are scattered while those for iron and mercury are not available

Except for iron, manganese, and, to a lesser degree, cobalt, all metals studied are found in much greater concentrations in the sewage particulate than in the local natural sediments (10). Since zinc, silver, chromium, copper, lead, and cadmium are not likely to be mobilized, and since they are comparatively scarce in natural sediments, one would expect the relative concentrations of these metals to be similar in sewage particulate and in the top layers of the sediments adjacent to the outfall. Table III shows a comparison of these concentrations normalized to that of zinc. The first column corresponds to the data published by SCCWRP for the average concentrations of metals in the total sewage for 1971. The second column is Galloway's measurement of a one-week composite of metal concentrations in sewage particulate. (The actual metal concentrations corresponding to column two are about 40% lower than those corresponding to column one—e.g., the total concentration of zinc in the sewage is reported as 2.4 mg l^{-1}; the concentration of zinc in the particulate fraction is 4100 mg kg^{-1} while the average total suspended solids is 330 mg l^{-1}—this is equivalent to 1.4 mg l^{-1} of zinc in sewage. However, the relative concentrations are in reasonably good agreement.) Cobalt, nickel, and manganese are seen to be twice as concentrated in the total sewage as in the particulate, in agreement with their particulate and soluble fractions as previously mentioned. The numbers given in columns three and four of Table III have been obtained from the average of concentrations reported by Galloway for the top 4 cm of box cores B20 and B21, situated right at the "Y" outfall and about one mile N-W of it, respectively.

The values for zinc (of course!), silver, chromium, and copper show fairly good agreement in the four columns as expected. Lead and cadmium show unexpected relative enrichment in the sediments. For the remaining three metals—cobalt, nickel, and manganese—significant fractions of which are soluble in the sewage, only the last three columns should be compared. The numbers for cobalt show fair agreement, probably fortuitously so, given the ±100% error reported for the core data, the possibility of cobalt mobilization, and the high background of cobalt in sediments. Nickel is clearly mobilized while manganese is much more concentrated in the sediments than the sewage particulate, reflecting the large natural abundance of manganese in the area. The same situation is to be expected for iron.

Figure 3, obtained by normalizing the surface concentrations of metals in various Phleger and box cores to that of the surface concentration of B20, demonstrates that the relative metal concentrations are more or less conserved throughout the surface of the reduced sediments. Despite some scatter in the data, the figure suggests strongly that metal concentrations in the reduced sediments depend solely on the position of the sample. This is in agreement with the no-mobilization hypothesis.

A study of relative metal concentrations in the surface sediments thus demonstrates only one major discrepancy with the simple expected result: a relative enrichment of lead and cadmium. This difficulty can be resolved in three ways: (1) One can question the data, which leaves no possible conclusion until more data are gathered; (2) a mobilization of unknown nature can be postulated for all metals. Similar mobilization of Zn, Ag, Cr, and Cu, higher than that of Pb and Cd would explain the data; (3) the no-mobilization hypothesis can be upheld and relative enrichment of lead and cadmium has then to be explained.

Although the success of the no-mobilization hypothesis as shown by Figure 3 and the top four lines of Table III argues against it, mobilization (second alternative above) cannot be disproved and has in fact been postulated by Galloway (3) and Hendricks (11) to explain the data. We shall pursue the third hypothesis—no-mobilization—and demonstrate that it is consistent with estimated sedimentation rates and that plausible mechanisms for enrichment of lead and cadmium exist.

Having studied the similarities that metal concentrations in sewage particulate and in the sediments exhibit relative to one another, one has to remember that metal concentrations in the sediments are about three times smaller than those in the sewage particulate. Why? Is this consistent with what we know of the fate of the sewage? Two possible explanations can be entertained: First, and contrary to the no-mobilization hypothesis, the metals might be mobilized from the particulate during and after settling to the ocean floor. Second, an increase in the bulk mass of the particulate might be taking place either through oxidation or by mixing with natural sediments, thus apparently "diluting" the metal concentration. The second explanation would be consistent with the no-mobilization hypothesis.

To decide which of these two mechanisms is more likely, a new piece of experimental information is needed. It is provided by Myers' studies of organic carbon concentrations (12). Myers' experiments demonstrate minimal reduction of organic carbon concentration in the particulate of aerated JWPCP sewage-seawater mixtures over 24 hr. Under anaerobic conditions no significant decrease in organic carbon concentration is seen for periods up to a month, probably due to incomplete oxidation of organics by sulfate. It seems thus logical to extend the no-mobilization hypothesis to the organic fraction of sewage particulate that reaches the nearby reduced sediments. Organic carbon concentrations (12) in sewage particulate (34%), natural particulate (1%), and the top 4 cm of cores B20 and B21 (11%) would then imply a ratio of about 2 to 1 for the rates of sedimentation of natural particulate over that of sewage origin in the area of these cores. This is about the ratio that would explain the concentrations of Zn, Ag, Cr, and Cu at the surface of these cores if data consistent with that of SCCWRP are used for concentrations of metals in sewage particulate. (That is, Zn: 7200 mg kg^{-1} in sewage particulate; 130 mg kg^{-1} in natural particulate; 2400 mg kg^{-1} in the top 4 cm of B20 and B21.)

By integrating the total mass of organic carbon accumulated near the outfall, Myers has estimated that only about 0.5% of the total sewage organic carbon can be accounted for in the reduced sediments. Since we are hypothesizing that no significant mobilization of any kind is taking place in this area, it is crucial to verify that this is consistent with the aquatic transport and settling characteristics of the sewage particulate. Figure 4 presents typical results obtained in the laboratory with a sedimentation column. First it should be noted that within the scatter of the data, the metals seem to settle at the same rate as the bulk of the sewage particulate. This was implicitly assumed in the preceding discussion.

Second, the dramatic differences between the sedimentation velocities observed in undiluted sewage and in sewage-seawater mixtures can be shown to be primarily an effect of the dilution: Through serial dilutions and multilevel sampling of the sedimentation column, interactions—flocculation, coagulation—between particles can be demonstrated to take place, increasing apparent sedimentation velocities of the suspensions more concentrated in sewage. [Sedimentation velocities can be greatly overestimated in sedimentation column experiments. There is no easy way to measure what actual sedimentation velocities are for the high dilution of sewage in the plume, since even for the maximum sewage-seawater dilutions practicable in the laboratory (1:30), particle interaction can be shown to take place. It should also be noted that comparison of various sedimentation column experiments is rendered difficult by the critical importance of the positioning of the sampler.] By use of an average plume height of 20 meters and maximum settling time of 24 hr it is estimated that only these particles with sedimentation velocities in excess of 10^{-2} cm sec^{-1} will reach the reduced sediments. For experiments at 1:10 dilutions, 3 ± 2% of the total sewage particulate is found to settle faster than 10^{-2} cm sec^{-1}. This can be said to be consistent with an estimate of 0.5% of the total sewage particulate settling in the reduced sediments adjacent to the outfall.

Estimating that half a percent of the total suspended solid mass discharged through the outfall in 1971 (330 mg $L^{-1} \times 5.4\ 10^{11}$ L) settles over an area of about 15 km^2, one obtains an average sedimentation rate of about 6 mg $year^{-1}$ cm^{-2} for the sewage particulate over the reduced area. This is to be compared with 9 mg $year^{-1}$ cm^{-2} reported by Emery (13) as the natural sedimentation rate in this region. However, in the immediate vicinity of the outfall, the sedimentation rate of sewage particulate is likely to be much higher than the computed average value so that some explanation has to be found for the expected 2 to 1 ratio of natural sewage sedimentation rates over cores B20 and B21. In this respect, it should be noted that the interactions observed among particles in sedimentation column experiments are likely to take place in the plume as well, and that the sedimentation rate of natural particulate is probably increased significantly by the presence of the sewage particulate. This point has been made by Myers as has the probable increase in productivity and thus in "natural particulate"—near the outfall. Further study is indicated for these phenomena. The relative sedimentation rates of natural and sewage particulate implied by the no-mobilization hypothesis do not seem unlikely in any case.

It remains to explain the relative enrichment of lead and cadmium. A possible explanation is that lead and cadmium are much more abundant than expected in the "natural" particulate near the outfall. This could be mediated by preferential uptake of these metals by microorganisms. Another explanation is that lead and cadmium particles settle faster than the bulk sewage particulate. Data such as presented in Figure 4 do not confirm or contradict this possibility, but the consistency of lead and cadmium with other metals in Figure 3 argues against it. Also it is intriguing to note that lead and cadmium are the only two metals for which settling of airborne particles could contribute significantly to the deposition in the sediments (10). Flocculation of these particles with sewage particulate in the water column could lead to the relative enrichment of lead and cadmium in the sediment.

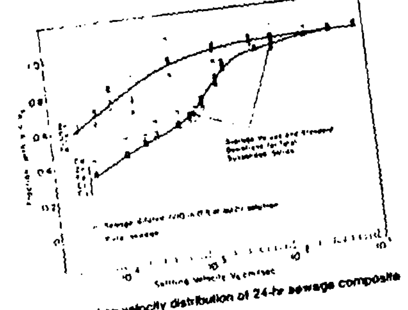


Figure 4. Settling velocity distribution of 24-hr sewage composite

Whatever the mechanism of enrichment, it should be noted that since only 0.5% of the total sewage particulate is postulated to settle in the reduced area, even a small supplementary source or differential settling behavior of lead and cadmium would explain the relative enrichment in the sediments adjacent to the outfall. Elucidation of the actual mechanisms involved in differentiating the fate of lead and cadmium from that of other metals is clearly an important area for further research. So far we are merely speculating.

Conclusion

In the particular case of the Los Angeles County sewage outfall system, it seems that much insight can be gained into the factors that govern the fate of trace metals by using chemical equilibrium models. It is argued that metals transported in the farfield tend to be solubilized by dilution and oxidation and that the objective—not necessarily desirable—of effective waste dispersion is well met in their case. An extremely simple interpretation of existing data on the metal content of the reduced sediments near the outfall is proposed, where the only significant phenomenon is a mixing of "natural" and sewage particulate without significant mobilization of any kind for most metals. Consistent with this interpretation is an estimate that on the order of 1% of the total sewage particulate—and 1% of the total sewage metals—is deposited. Myers has estimated that 0.5% of the sewage organics could be accounted for in these sediments. Differences in the fate of various metals can, in some cases, be explained on the basis of different chemical behavior—e.g., the more soluble characteristics of cobalt, nickel, and manganese—while in other cases, differences in physical (sedimentation, flocculation) or biological (microorganism uptake) behavior have to be postulated to explain the data as is the case for the relative enrichment of lead and cadmium in the reduced sediments.

This study points out important research needs in the area of analytical chemistry of wastewaters as well as in the area of physical transportation processes in coastal waters. Specifically a new direct or indirect method of evaluating the oxidation-reduction level of reduced solutions should be developed, and much theoretical and experimental research on the interactions of suspended particulate matter is necessary to upgrade our understanding of the fate of metal pollutants in waste water.

It should be emphasized that the very reduced and metal-rich nature of the JWPCP sewage is not typical of all sewage discharged from marine outfalls. For example, Chen and Rohatgi (14) have found the metals in the Los Angeles City sewage to be rather easily solubilized in contrast to the situation in the Los Angeles County sewage—reflecting assuredly the differences in treatment processes. Extension of the methodologies used in this study to other particular situations is certainly warranted; extension of the results is not.

Acknowledgment

The authors wish to thank E. P. Myers for stimulating discussions, R. E. McDuff for help in performing some of the computations, and C. Chakoumakos for providing an inspirational setting in the woods of Maine.

Literature Cited

(1) Brooks, N. H., "Predictions of Sedimentation and Dilution of Digested Sludge in Santa Monica Bay," Report to Hyperion Engineers, August 1956.
(2) "The Ecology of the Southern California Bight: Implications for Water Quality Management," Southern California Coastal Water Research Project Rep. Tech Rep 104, March 1973.
(3) Galloway J. N., "Man's Alteration of the Natural Geochemical Cycle of Selected Trace Metals," PhD Thesis, University of California at San Diego, 1972.
(4) Morel, F., Morgan, J., *Environ. Sci. Technol.*, 6, 58 (1972).
(5) McDuff R. E., Morel, F., "REDEQL, A General Program for the Computation of Chemical Equilibrium in Aqueous Systems," Tech Rep EQ-72-01, Keck Laboratories, California Institute of Technology, Pasadena, Calif., 1972.
(6) Lawrence, A. W., McCarty, P. L., *J. Water Pollut. Contr. Fed.*, 37, 392 (1965).
(7) Manka, J., Rebhun, M., Mandelbaum, A., Bortinger, A., *Environ. Sci. Technol.*, 8, 1017 (1974).
(8) James, R. O., Healy, T. W., *J. Colloid Interface Sci.* 40, 42 (1972).
(9) Grigg, R. W., Kiwala, R. S., *Calif. Fish Game*, 56, 145 (1970).
(10) Bruland, K. W., Bertine, K., Koide, M., Goldberg, E. D., "History of Metal Pollution in Southern California Coastal Zone," Environ. Sci. Technol., 8, 425–32 (1974).
(11) Hendricks, T. J., Young, D. R., "Modeling the Fates of Metals in Ocean-Discharged Wastewaters," Southern California Coastal Water Research Project Rep. Tech Rep. 208 January (1974).
(12) Myers, E. P., "The Concentration and Isotopic Composition of Carbon in Marine Sediments Affected by a Sewage Discharge," PhD Thesis, California Institute of Technology, Pasadena, Calif., 1974.
(13) Emery, K. O., "The Sea Off Southern California," Wiley & Sons, New York, N.Y., 1960.
(14) Chen, K. Y., Rohatgi, N., "Transport of Trace Metals in Suspended Particulates Upon Mixing with Sea Water," Rep to Southern California Coastal Water Research Project, 1974.

Received for review November 13, 1974. Accepted April 21, 1975. Financial support from the Rockefeller Foundation and the Environmental Protection Agency Grant No. 51205 is gratefully acknowledged.

METROPOLITAN
WASTE
CONTROL
COMMISSION
Twin Cities Area

01450

February 15, 1978

Mr. Bruce Brott
Minnesota Pollution Control Agency
1935 W. County Road B2
Roseville, MN 55113

Subject: Metro WWTP Ash Disposal Project

Dear Mr. Brott:

Enclosed is the operational report form for the month of January.

Lagoons No. 1 and 2 have been completely excavated and no more ash will be deposited on the landfill until our interim ash disposal report is submitted to the Agency.

If there are any questions, please contact us.

Very truly yours,

B.J. Harrington/BDW
Bernard J. Harrington
Director of Engineering

BJH:WGM:bdw
Enclosure

cc: Roger Acton, MWCC/attachment
G. W. Lusher, MWCC/attachment
W. K. Johnson, MWCC/attachment

350 METRO SQUARE BLDG.
7TH & ROBERT STREETS
SAINT PAUL MN 55101
612 222-8423

1010068

01451

TO: MINNESOTA POLLUTION CONTROL AGENCY
Division of Solid Waste
1935 West County Road B2
Roseville, MN 55113

OPERATIONAL REPORT

MONTH OF January, 1978

Facility Name Metropolitan Waste Control Commission

Permit Number SW-189 Operator: Name

Address

Phone

I. SOLID WASTE

SOLID WASTE DEPOSITED	#Vehicles	Cubic Yds.	Type[1]
Commercial vehicles packers 10 cubic yds. and over Vehicles under 10 cubic yards Private vehicles: auto, pick-up and trailers	14	79,532	0
TOTALS			

[1]Types: R-residential I-industrial C-commercial
A-agricultural O-other (explain, demolition debris, tires, trees, etc.)

0 = Incinerated Sewage Sludge Ash

MPCA-589

1010067

V. PROGRESS REPORT (status of construction and/or operation).

Excavation of ash ponds and disposal of material is 100% complete as of January 31, 1978

VI. OPERATIONAL PROBLEMS AND REMARKS

None

Signature

II. TOXIC AND HAZARDOUS WASTES

TYPE	AMOUNT(#yds. or gal.)	Vehicles	Origin[2]
TOTALS			

[2]Origin: Place of generation, be specific

B. If Toxic and Hazardous Wastes are received and transported away from the site, give name of permitted facility at which they are deposited: __________

I. RATE OF SITE UTILIZATION

A. 1. Area presently being filled (with respect to site plans). Central and Southern areas

2. Amount of land used: 23 acres acres of sq. yds.

3. Height of Lift: 2 to 3 feet

B. Cover Material

1. Amount used 20,000 cubic yards

2. Source and Type Surplus excavated earth material from construction sites at Metropolitan Wastewater Treatment Plant

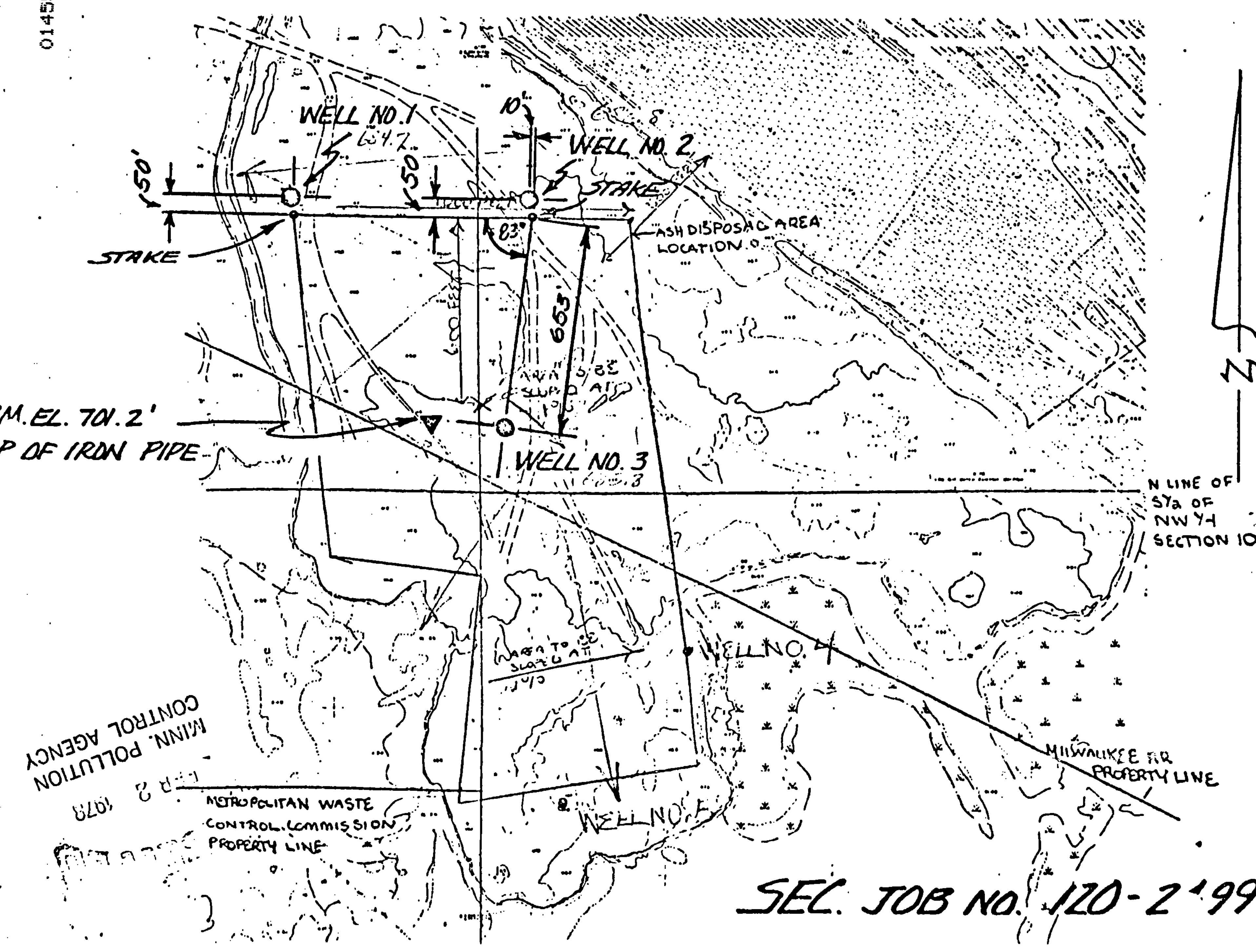
IV. ANALYSIS OF GROUNDWATER MONITORING (as identified in plan).

01454

1010064

01455

1010063



SEC. JOB NO. 120-2499

01456

Metropolitan Waste Control Commission

Hydrogeologic Investigation of Ash Disposal Site on the St. Paul Landfill

ED | CH2M HILL
A JOINT VENTURE

December 1979

1110202

3-12-82

~~To~~ From: Dave Maschwitz
DWQ, M & A

~~From:~~ To: Mike Tibbetts
SHWD, Reg. Comp.

over

[illegible] is the report for the Pig's Eye Dump and Ash lagoons we were talking about on 3-10-82. As mentioned, there was [illegible] g.w. monitoring at this site. If you have further questions [illegible] dump, call Jerry Stahnke @ 87-7733

P.S. Return report when you are done

1110201

CED | CH2M HILL
A JOINT VENTURE

December 5, 1979
L10772.K0

Reply to:

James E. Schwing, P.E.
CH2M HILL
7851 Metro Parkway, #205
Minneapolis, MN 55420

Mr. Richard J. Dougherty
Chief Administrator
Metropolitan Waste Control Commission
350 Metro Square Building
7th and Robert Streets
St. Paul, Minnesota 55101

Dear Mr. Dougherty:

Subject: Hydrogeologic investigation of St. Paul landfill

Attached is our report of the hydrogeologic investigation of the abandoned St. Paul landfill relative to use of this area for disposal of ash produced at the Metropolitan Wastewater Treatment Plant.

The study reported herein was authorized by the Commission in their letter to CED/CH2M HILL dated 28 September 1979. This report discusses the effect on the ground water that the previous ash disposal project caused at the St. Paul landfill in light of other influences on the ground water at this site caused by previous landfilling practices and external influences on the landfill's ground water quality.

We appreciate the opportunity of providing this service to the Commission and we will be available for any subsequent questions you may have concerning this report.

Very truly yours,

James E. Schwing

James E. Schwing, P.E.
Project Manager

js

1110199

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Registered Professional Engineer under the Laws of the State of Minnesota.

Date 11/28/79 Reg. No. 0103729

SUMMARY AND CONCLUSIONS

This report presents results of a study to determine if there was an adverse impact on the ground water quality following the disposal of sludge incinerator ash by the Metropolitan Waste Control Commission on the abandoned St. Paul (Pigs Eye) Landfill.

The St. Paul Landfill was operated from about 1956 to 1971 and contains residential, commercial, and industrial wastes and chemicals. In December 1977, through January 1978, the Metropolitan Waste Control Commission (MWCC) applied 136,000 cubic yards of ash, two to four feet thick, over 31 acres of the abandoned landfill. Up to six inches of topsoil was then applied on top of the ash and seeded.

The landfill and ash disposal site is located on an alluvial bar, with the ground water levels directly influenced by the stage of the Mississippi River. Most of the ground water beneath the study area enters as surface water from either the Mississippi River or Battle Creek north of the ash disposal site and exits as surface water into Pigs Eye Lake and the Mississippi River to the south of the site. The ground water gradients and flow rates across the ash disposal site are very low and not constant.

Six months prior to the ash disposal, the MWCC began sampling the ground water from a monitoring well network on the ash disposal site. The water levels in these wells were measured and ground water samples were taken and analyzed for various parameters, such as heavy metals, pH, and alkalinity. It was determined from ground water samples prior to the ash disposal, that the ground water did not meet drinking water standards.

The monitoring data indicates that some change did occur in ground water quality (Table 6), but these changes also occurred in water from a well that was up-gradient of the ash disposal site, and also in a down-gradient well not presently affected by leachate that has percolated through the ash. This suggests that the indicated changes in ground water quality are from a source other than the ash. A detailed evaluation of the other possible sources or the mechanisms was not made, but indications are that the changes were due to a decrease in pH. This decrease in pH could increase the solubility of certain metals already contained in the landfill.

The magnitude of the apparent change in ground water quality was small and is of reduced importance considering that the ground water quality did not meet drinking water standards prior to the ash disposal. Also, since the site is 200 feet below areas where shallow ground water is used, and the bedrock aquifer discharges into the Mississippi River floodplain, the ground water beneath the site is no threat to any usable ground water supply in the Twin Cities area.

Results of this study indicate that ground water changes have not been due to the overlayment of ash. Further overlayment of ash would not have a deleterious effect on ground water quality. For these reasons it is recommended that the Commission proceed with the proposed project to dispose of additional ash on the St. Paul Landfill.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

INTRODUCTION

PURPOSE AND SCOPE

The purpose of the study reported herein was to determine if there was an adverse impact on the ground water following the disposal of sludge incinerator ash by the Metropolitan Waste Control Commission (MWCC) on the abandoned Pigs Eye Landfill. The ash was generated at the MWCC's Metro Plant and disposed on this site during the winter of 1977-1978. The MWCC proposes to dispose of additional ash from the Metro Plant at this site. From the results of a monitoring program of the past ash disposal project and available information on the hydrogeology of the site, the technical feasibility of the proposed project will be assessed.

The scope of this study was to determine if:

1. Leachate has migrated from the past disposed ash, through the refuse and soil, to the ground water, and was sampled by monitoring wells.

2. Ground water quality as it existed prior to deposition of the ash was not adversely impacted by the ash disposal.

This report will discuss the history of the ash disposal site and a general overview of leachate production and attenuation. Then the physical setting of the site, including subsurface geology will be presented. Results of the ground water monitoring program instituted by the MWCC at the landfill will be analyzed to determine ground water flow rates and if there are any apparent changes in ground water quality.

Because of time limitations on this project, only information that was readily available was used. Information for this study was obtained from the MWCC, Minnesota Pollution Control Agency (MPCA), U. S. Geological Survey, and the Metropolitan Council.

HISTORY OF SITE

The ash disposal site is located on the abandoned St. Paul (Pigs Eye) Landfill north of Pigs Eye Lake and adjacent to the Metro Plant. This landfill was operated by the city of St. Paul from about 1956 to 1971. Residential, commercial, and industrial refuse was deposited in the landfill. Industrial chemicals in liquid and containerized drums were also put into the landfill (Ref. 1). Up to two lifts of refuse, each being six feet deep, were deposited over an area of about 80 acres. An estimated 8.23 million cubic yards of refuse are contained in the landfill (Ref. 2).

1110191

In November 1977, a permit was issued by the MPCA to the MWCC allowing 150,000 cubic yards of sludge incinerator ash to be spread over the abandoned landfill. A copy of this permit is contained in Appendix A of this report.

Starting in December 1977, and finishing in January 1978, sludge incinerator ash from two ash lagoons east of the Metro Plant was spread over about 31 acres of the landfill. The depth of the ash varies from two to four feet, with approximately 136,000 cubic yards of ash applied. Following the ash disposal, six inches of topsoil were applied on top of the ash and then seeded with grass.

GENERAL THEORY OF LEACHATE PRODUCTION AND ATTENUATION

The following is a general overview of leachate production and how its strength is attenuated as it passes through the soil and is mixed with the ground water.

Leachate is water that has come into contact with solid waste in a landfill and has been contaminated with elements or compounds extracted from materials in the landfill. The primary source of water for leachate production is rain that infiltrates into the soil. However, if the landfill is below the water table, ground water can also be a major contributor to leachate production.

The quantity of leachate generated by infiltration is dependent on the water balance for the site. This includes precipitation, surface runoff, evapotranspiration, and the field capacity of the landfill. The field capacity of a landfill is the moisture content at which gravity drainage of water will occur. The field capacity must be reached prior to the generation of leachate. The Pigs Eye Landfill, due to its age and because it is partly below ground water, probably attained field capacity many years ago. Water balance methods are described in a number of sources, but generally, 40 to 50 percent of the annual precipitation enters a sanitary landfill and results in leachate (Refs. 3 and 4).

Leachate quality is dependent on many interacting factors:

- Composition of the solid waste
- Age of the landfill
- Water content of the landfill
- Thickness and compaction of the solid waste
- Type of surface cover over the landfill

The type of waste in a landfill is generally the most important factor determining leachate quality. This is especially important when considering that the Pigs Eye Landfill contains industrial wastes and chemicals.

The age of a landfill is also important, because the concentration of constituents in leachate generally decreases with time (Ref. 5). Attenuation, or the reduction of leachate strength, as it flows through the soil can be from physical/chemical changes resulting from contact with soil, biological changes from microorganisms, and dilution within the ground water. Physical/chemical changes include: chemical precipitation, ion exchange, adsorption, oxidation-reduction, and chelation.

Biological changes occur from soil microorganisms utilizing organic compounds in the leachate. This biological activity reduces the concentration of organic compounds, but can also increase the solubility of metals by creating a reducing environment (anaerobic) and producing organic acids or carbon dioxide resulting in lowering the pH. It is generally felt that the large amount of carbon dioxide that is generated in a landfill combines with leachate to form a weak acid. This increases the leachate's ability to dissolve chemicals from the solid waste. The addition of lime on a landfill can be used to keep the pH high enough to minimize the mobility of metals. The ash that was deposited on the landfill contained a large percentage of lime, due to conditioning of the sludge with lime prior to dewatering. Therefore, it was felt that the addition of the ash could increase the pH of the leachate, thereby reducing the mobility of metals.

Upon entering the ground water, leachate strength is reduced by diffusion and dispersion. Diffusion is due to the concentration difference between leachate and ground water. Dispersion occurs as a result of physical mixing from flow around pores and fractures in the subsurface aquifer.

PHYSICAL SETTING

The ash disposal site overlies a portion of the abandoned Pigs Eye Landfill. The site is located on an alluvial bar on the east side of the Mississippi River floodplain, 5 to 15 feet above the river and about 200 feet below the general land surface outside the floodplain. Figure 1 shows the general study area location. Except for Pigs Eye Lake to the south, the area is surrounded by industrial facilities. These include a large railroad yard to the east and north, petroleum and industrial molasses storage and loading facilities to the northwest and west, and the Metropolitan Wastewater Treatment Plant to the west.

It was noted during a site inspection on October 12, 1979, that the entire area is relatively flat, covered with vegetation, and harbors considerable wildlife. The old landfill is clearly evident where the previous ash disposal project did not cover the landfill.

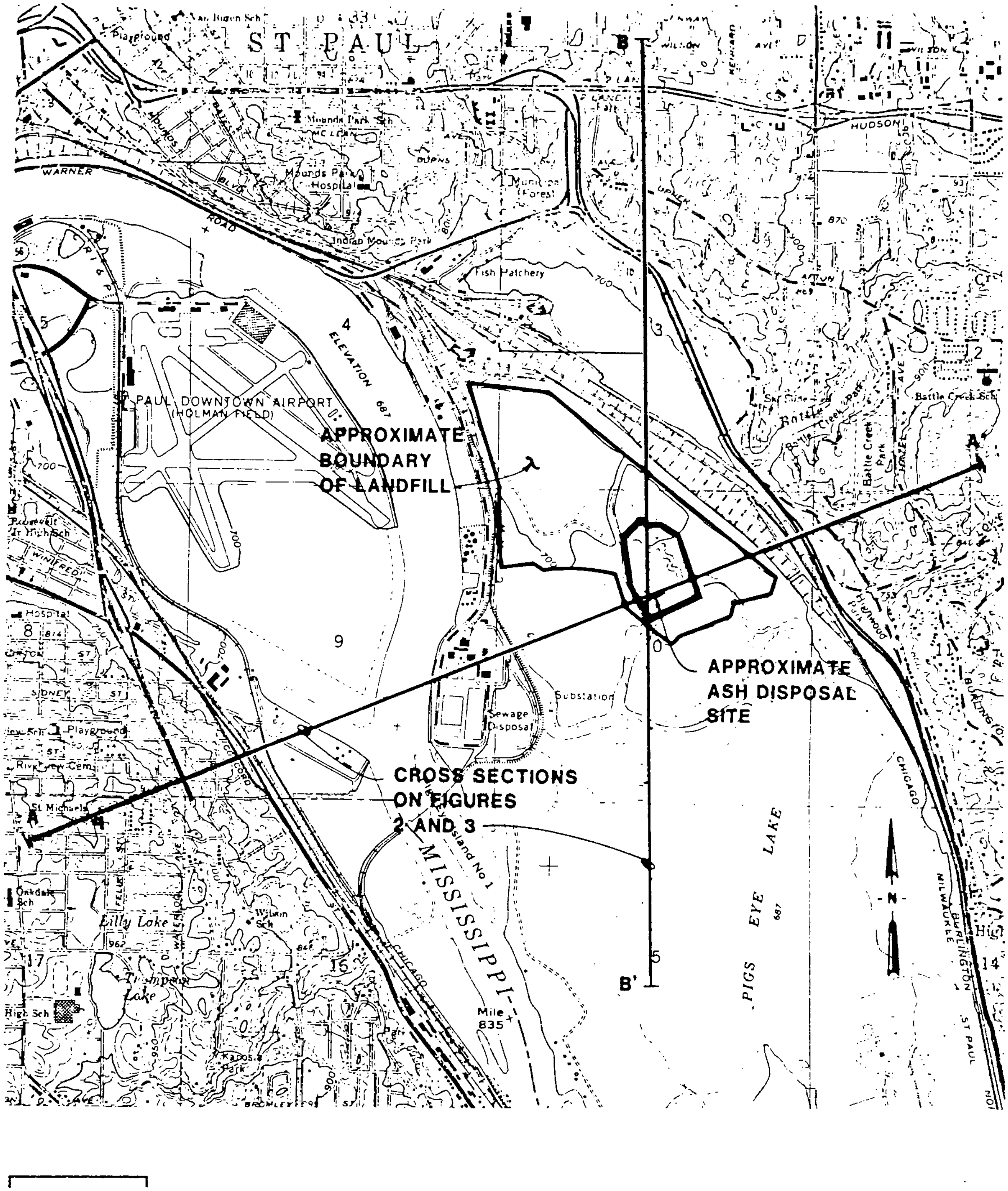
GEOLOGY

The alluvial bar that the landfill is on has been submerged several times in the past, being located in a floodplain. Test borings by the Soil Exploration Company (SEC) indicate that the area has alternated between alluvial bar and marsh at least four times (Ref. 6). The application of solid waste, and later ash, has elevated and stabilized the area somewhat. In addition, the area has been flooded periodically during high runoff periods, and this will probably reoccur in the future; however, flood control dikes and the increased elevation should decrease the frequency.

Soil Exploration Company's test borings indicate that subsurface conditions vary greatly beneath the site. Lenses and layers of sand, silt, clay, muck, and peat interfinger to bedrock, which is limestone of the Prairie du Chien Group. Depth to bedrock ranges from about 20 to just over 100 feet across the site. An old bedrock river channel runs from the north to the south through the area. Figures 2 and 3 are east-west (A-A') and north-south (B-B') cross sections of the general site area shown in Figure 1.

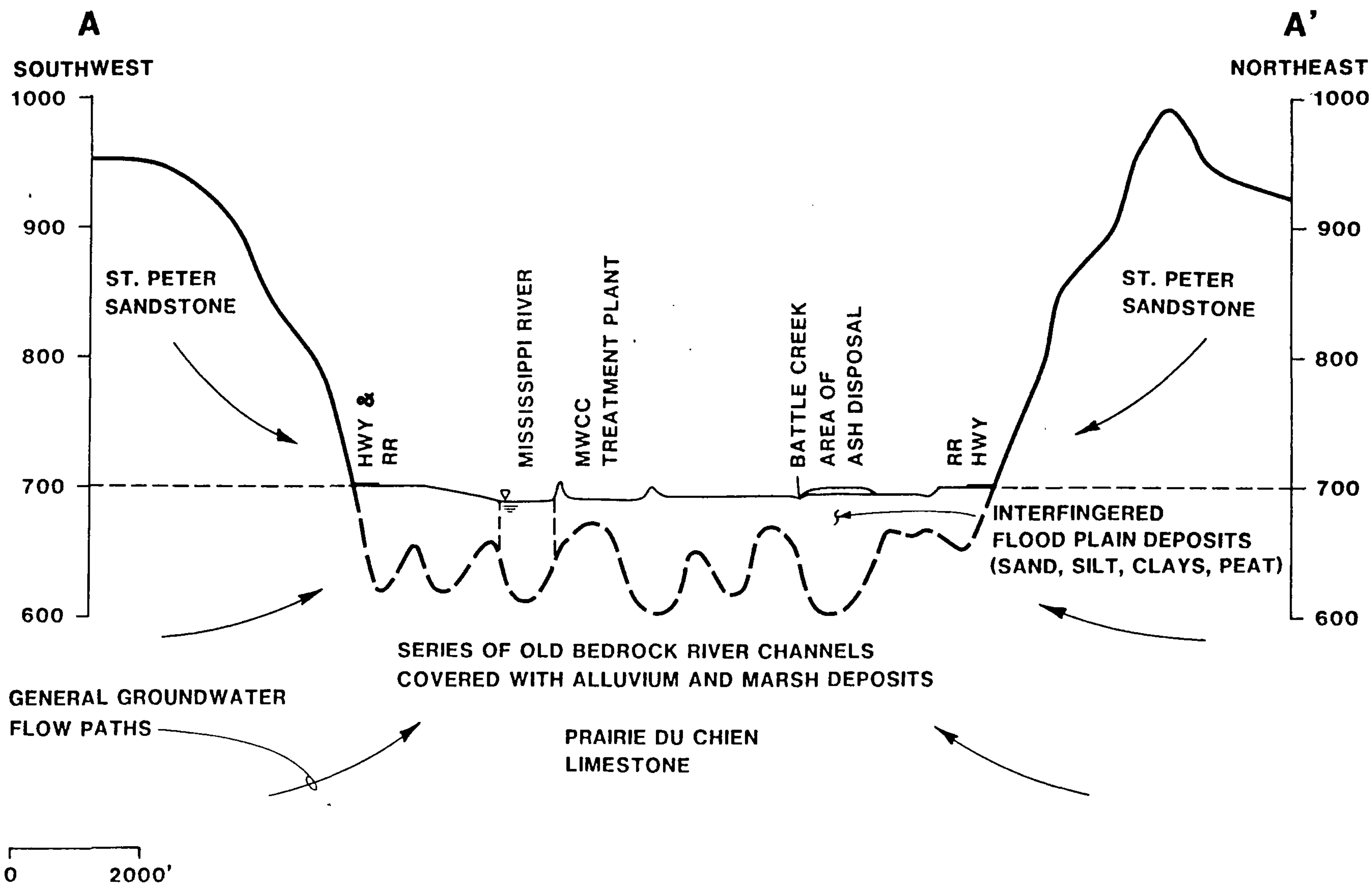
The U.S. Geological Survey topographic map of the area shows that prior to 1967, Battle Creek flowed diagonally across the site from northwest to southeast (Figure 1). The creek was rerouted along the west side of the ash disposal site between 1967 and 1972, as shown in Figure 4. Figure 4 shows some physical features and test boring locations at the ash disposal site. A cross-section (C-C') from Figure 4 was prepared from the test borings by the SEC and is presented in Figure 5. This figure shows the variability of the substrata.

01470



1110187

FIGURE 1
LOCATION OF ASH DISPOSAL SITE OVER ABANDONED PIGS EYE LANDFILL



PLAN SHOWN ON FIGURE 1
DATUM: MEAN SEA LEVEL

1110186

FIGURE 2
CROSS SECTION OF PIGS EYE LANDFILL AND MISSISSIPPI RIVER FLOODPLAIN

01471

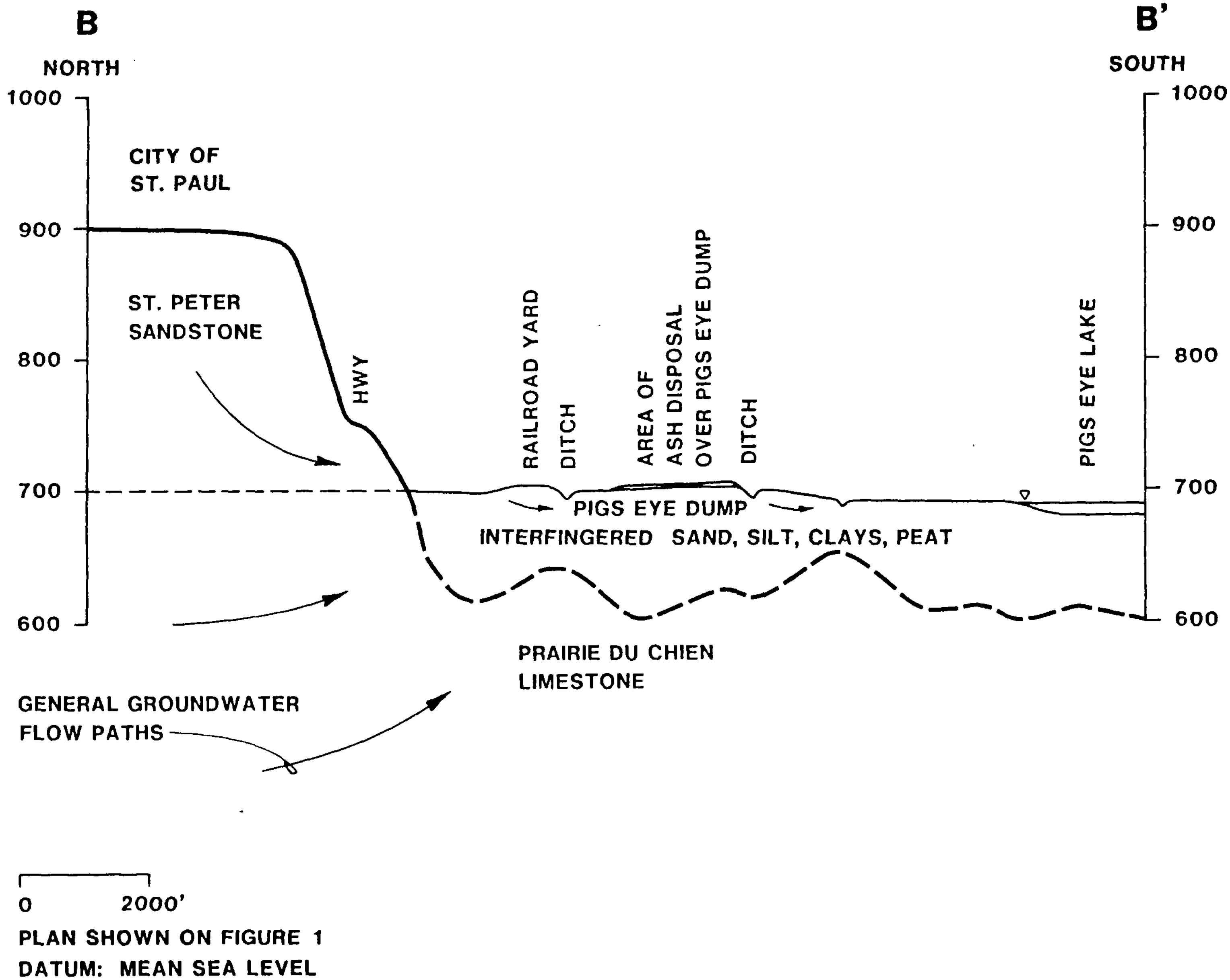


FIGURE 3
N/S CROSS SECTION
OF PIGS EYE LANDFILL

01472

1110185

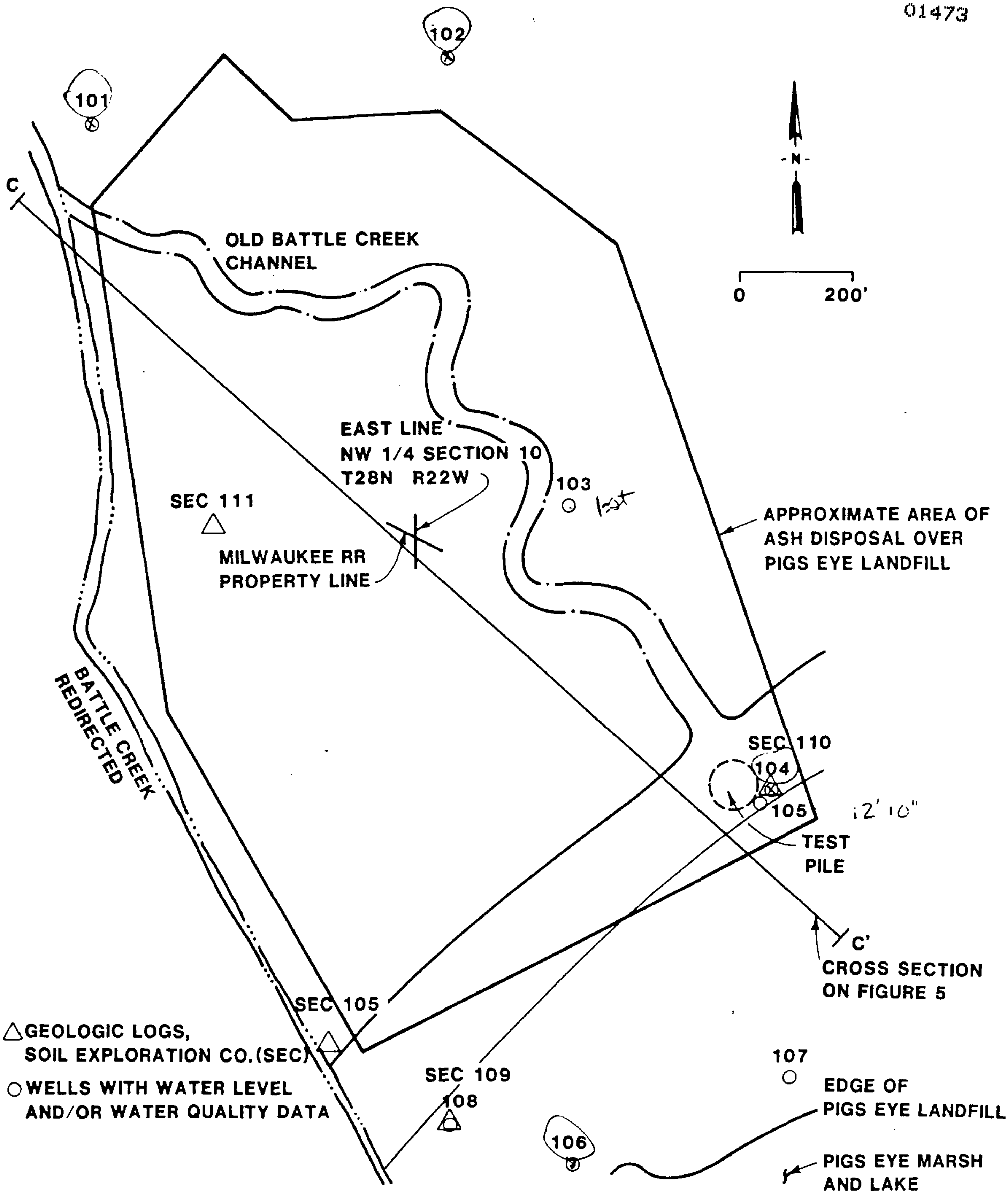
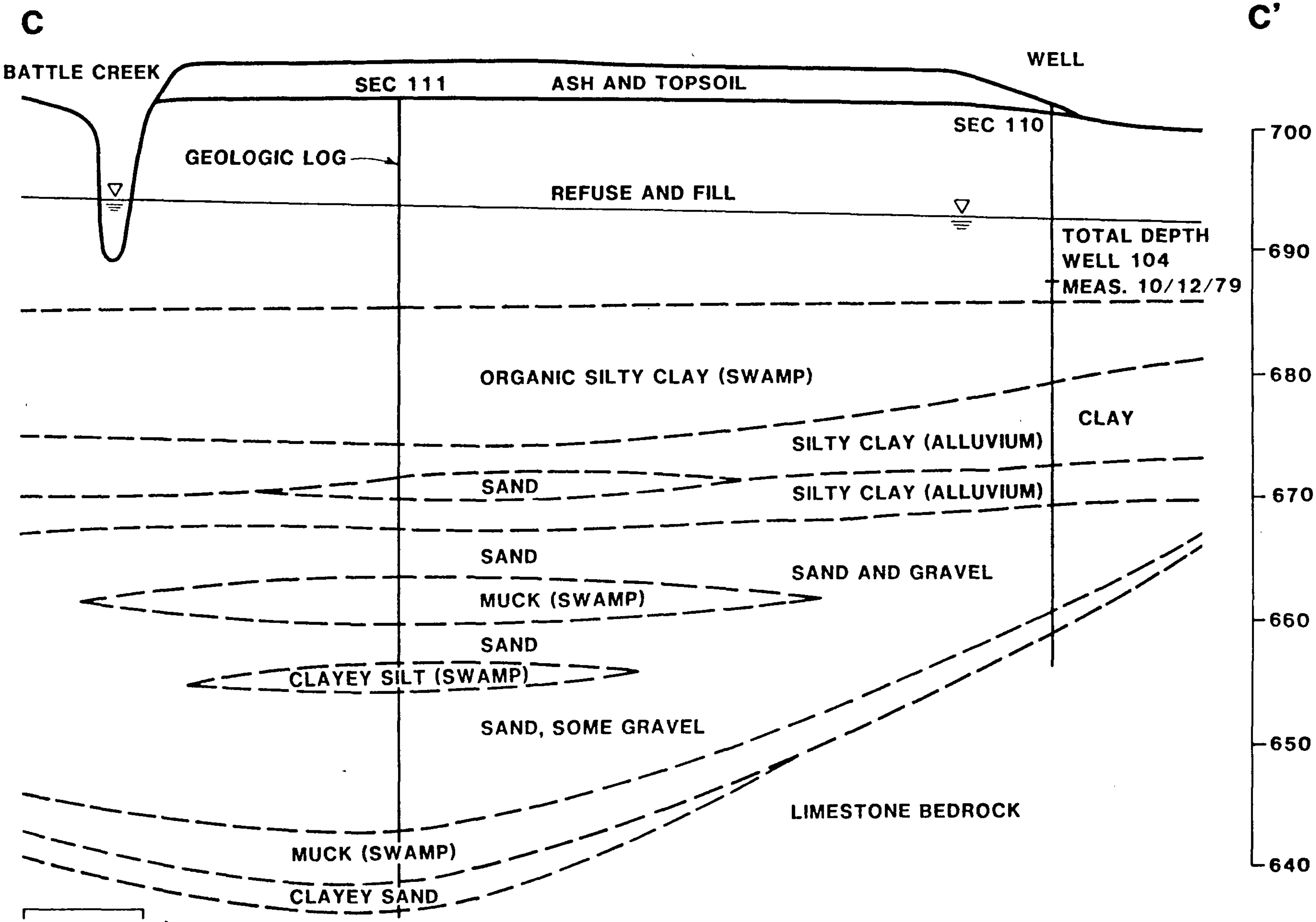


FIGURE 4
LOCATION OF WELLS AND PHYSICAL FEATURES OF ASH DISPOSAL SITE



DATUM: MEAN SEA LEVEL
PLAN SHOWN ON FIGURE 4

1110183

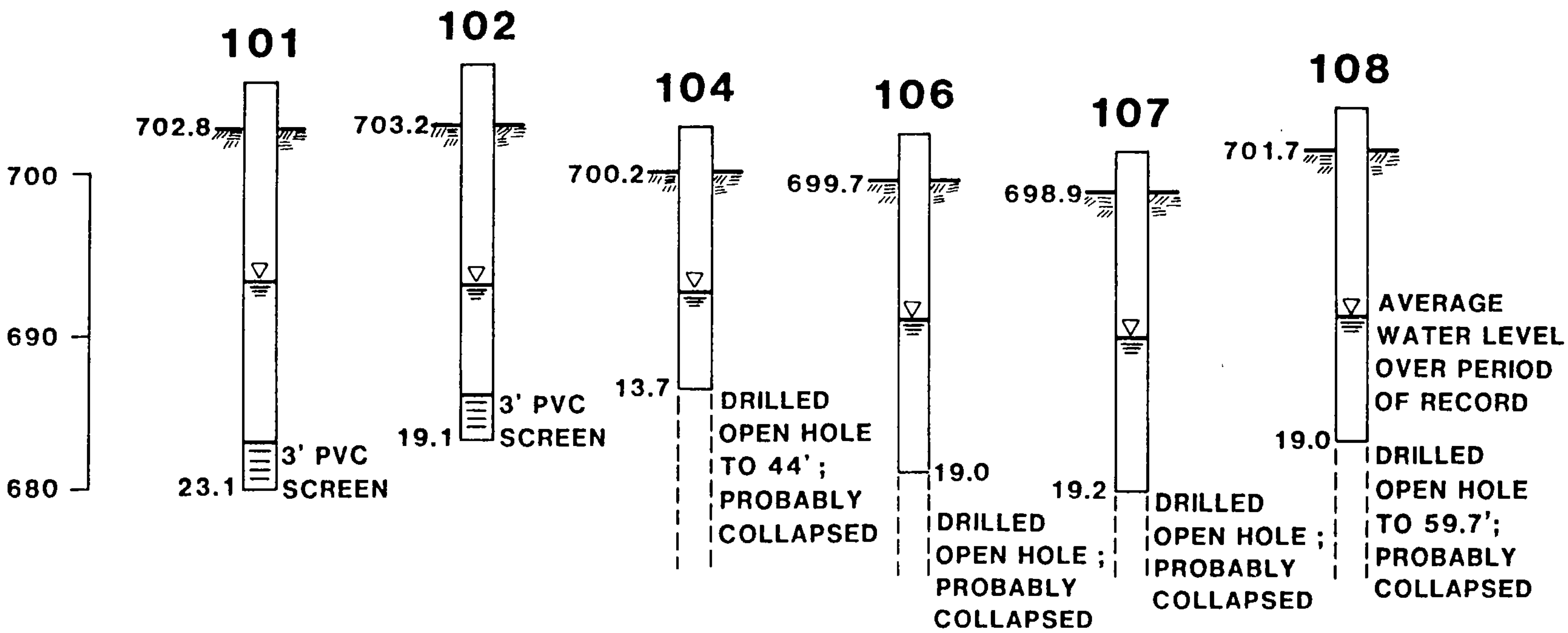
01474

FIGURE 5
NW/SE CROSS SECTION OF ASH DISPOSAL SITE

MONITORING WELLS

Prior to the ash disposal, the SEC installed numerous monitoring wells in the southern half of the landfill site during investigations for a proposed coal handling facility. Some of these wells were used by the MWCC for their monitoring program. In 1977, the SEC installed three more piezometers in the northern half of the ash disposal site for the MWCC. Currently, the MWCC monitors ground water levels and quality from four wells in the ash disposal site. In addition, some historical ground water levels and quality data were available from four additional wells. The locations of these eight monitoring wells are shown in Figure 4, with Table B-1 in Appendix B presenting the known construction details for each well. Figure 6 shows a cross section of these monitoring wells.

Over the years, as new wells were added to the MWCC monitoring system, and others destroyed, the wells were renumbered several times, often with overlapping numbers. To end the duplication of numbers, the entire well network was renumbered. Table B-2 in Appendix B shows the new numbers as well as the previously used numbers for correlation. MPCA's six digit well number should be retained on ground water level and quality data reports submitted to that agency.



DATUM: MEAN SEA LEVEL

FIGURE 6
CROSS SECTION OF MONITORING WELLS

GROUND WATER MOVEMENT AND QUALITY

PIEZOMETRIC SURFACE

The landfill area is completely surrounded by bodies of surface water. Ground water levels are directly influenced by changes in the stage of these adjacent bodies. The Mississippi River is the dominant factor controlling water levels of both the surface and ground water at the site. Since the Mississippi River flows south, the overall movement of ground water beneath the site is also to the south. On a smaller scale, however, the orientation and permeability of the underlying sediments causes considerable variance from this general southward flow.

Figures B-1 and B-2 in Appendix B are a series of contour maps of the ground water table beneath the site prepared from monthly ground water level data collected by the MWCC since March 1979. The October 1979 measurements were taken by CED/CH2M HILL during an inspection of the site. The ground water configuration most commonly found during the monitoring program is presented in Figure 7. These ground water contours are generally accurate to show the direction of ground water movement and the slope of the ground water table. The hydrogeologic regime is very complicated when the subsurface materials are laterally and vertically mixed. Several more wells, a few surface water staff gauges, more geologic data, and a longer period of water level records are needed for a more precise picture of the water table in this area. However, the present information is sufficient to generally predict the fate of the ground water in the landfill, considering its intended use and past landfilling practices.

Examination of Figures B-1, B-2, and 7 reveals several interesting phenomena. There is an apparent zone of higher permeability extending from the northwest (well 101) to the southeast (well 104). This orientation corresponds with the old channel of Battle Creek and is more than likely directly related to it. As the stage in Battle Creek rises, ground water levels in this more permeable zone respond faster than those outside the zone and a ground water divide develops. The divide extending from well 101 to 104 splits the ash disposal area in two. Ground water to the south of the divide flows to the south and southwest while north of the divide it flows north and northeast. This ground water configuration was the most common found and is shown in Figure 7. On two occasions, the ground water flows uniformly south and southwest across the ash disposal area. This probably corresponds to a period of continued high surface water stages when the ground water is at equilibrium with the regional flow pattern established by the Mississippi River.

01478

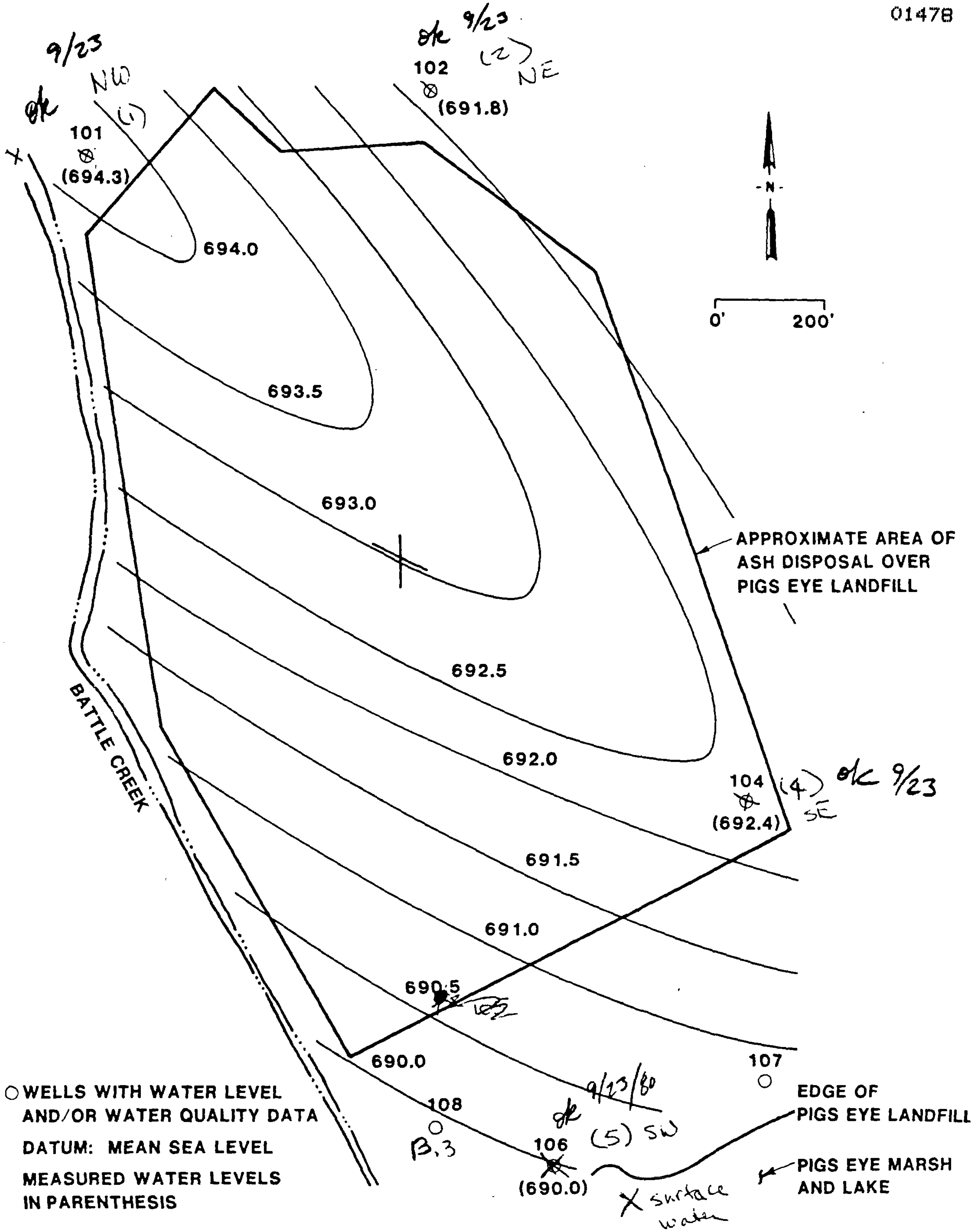


FIGURE 7
APPROXIMATE WATER TABLE CONTOURS - AUGUST 1979

1110179

The October 12, 1979 water table contours in Figure B-2 show the effects of about a 2 foot rise in the stage of Battle Creek in the vicinity of wells 106 and 108. This was due to the effect of a beaver dam on the water level in Battle Creek.

GROUND WATER GRADIENTS AND FLOW RATES

Ground water gradients are generally very low across the entire ash disposal site. The dominant factor controlling gradients and flow directions appears to be the stage of Battle Creek as transmitted through the old Battle Creek stream channel. Ground water generally moves into the site near well 101 and disperses to the north-east, south-east, and south towards wells 102, 104, and 106, respectively. There are occasional variations to this pattern, but over the period of record, this is the predominant flow regime. Examination of Figures B-1, B-2, and 7 reveal the following general conclusions regarding flow directions:

- Ground water gradients across the ash disposal site are very low and not constant.
- Well 101 is usually up-gradient of the other wells and is outside of the ash disposal site.
- Well 102 is outside the ash disposal site and is usually down-gradient from the north-west corner of the ash disposal site and well 101.
- Well 104 is in the ash disposal site and is almost always down-gradient from the bulk of the ash site and well 101.
- Well 106 is outside the ash disposal site and is consistently down-gradient of ash site and the other wells.

Flow rates and travel times between wells and from the ash disposal area to the wells can be calculated by using gradients from Figures B-1, B-2, and 7, and estimated permeabilities, as presented in Table 1. An estimated permeability of 1000 gal/day/sq ft was used in preparing Table 1. This value was based on the permeability of clean sand and gravel (Ref. 14) that could exist in the old Battle Creek channel, and the estimated permeability of the refuse in the landfill.

The times shown in Table 1 reflect minimum travel times and do not take into account the observed changing of the gradients and flow directions over time. However, these factors would be very difficult to account for in determining travel times. The following general conclusions can be made from Table 1 regarding migration of leachate from the ash to the monitoring wells during the time period since the ash was deposited.

Table 1
ESTIMATED GROUND WATER TRAVEL TIMES

DATE OF WATER LEVEL SAMPLE	FROM	TO	GRADIENT[a] (ft/ft)	VELOCITY[b] (ft/day)	DISTANCE BETWEEN POINTS (ft)	TRAVEL TIME BETWEEN POINTS[c] (days)
3/79	101	102	0.0032	0.42	630	1500
	101	104	0.0011	0.15	1660	11000
	EOA[d]	102	0.0032	0.42	220	525
	104	106	0.0059	0.79	740	940
	EOA[d]	106	0.0052	0.70	480	690
4/79	104	106	0.0022	0.29	740	2600
5/79	101	102	0.0033	0.44	630	1430
	101	104	0.0011	0.15	1660	11000
	EOA[d]	102	0.0033	0.44	200	455
	EOA[d]	106	0.0021	0.28	400	1430
7/79	EOA[d]	106	0.0027	0.36	400	1100
8/79	101	102	0.0044	0.59	630	1070
	101	104	0.0011	0.15	1660	11000
	EOA[d]	102	0.0046	0.62	200	324
	104	106	0.0032	0.42	740	1760
	EOA[d]	106	0.0032	0.42	500	1190
9/79	101	102	0.0045	0.61	630	1030
	101	104	0.0016	0.21	1660	7900
	EOA[d]	102	0.0060	0.85	200	236
	EOA[d]	106	0.0022	0.29	400	1375

[a] using water level contours (figs B-1, B-2, and 7) and distance between points.
[b] velocity = permeability x gradient; assumed permeability of 1000 gal/day/sq ft.
[c] travel time = distance between points ÷ velocity.
[d] edge of ash disposal area.

- Well 102 is probably close enough to the edge of the ash disposal site so that leachate that has percolated through the ash has been sampled. However, only a small portion of the ash disposal site would impact leachate flowing to this well.

- Well 104 is probably exposed to leachate from the ash, being located in the ash disposal site. The portion of the ash site that would contribute leachate flowing to this well extends approximately 100 feet to the northwest.

- Well 106 is consistently down-gradient of the ash disposal site, but due to the low flow rates, the ground water that has been sampled from this well has probably not been in contact with the ash.

It should also be noted that most of the ground water beneath the study area enters as surface water from either the Mississippi River or Battle Creek at the north and exits as surface water into Pigs Eye Lake and the Mississippi River to the south. Therefore, the ground water at the site is little more than very slow moving river water. This factor, combined with the possibility that the whole area is periodically inundated by flooding, suggests that most of the impact from the ash disposal and the old landfill will be on surface water quality in Pigs Eye Lake and the Mississippi River.

GROUND WATER QUALITY

This section will present and discuss the results from the ground water quality monitoring program conducted by the MWCC. In addition, the chemical and leaching characteristics of the ash that were deposited on the landfill will be presented.

Sludge Incinerator Ash Characteristics

The sludge incinerator ash that was applied to the landfill came from two ash ponds located east of the Metropolitan Wastewater Treatment Plant. This ash originated from the incineration of dewatered municipal wastewater sludge. The ash was sluiced to the settling ponds, with the supernatant from the ponds returned to the treatment plant.

Chemical characteristics of the sludge incinerator ash that was deposited on the landfill site are shown in Table 2. The ash has a high pH due to conditioning of the sludge with lime and ferric chloride prior to dewatering. This also increases the calcium and iron concentrations in the ash.

A leachate test was run by the MWCC on the ash in the ponds on June 8, 1977. The test was performed using a leachate test prescribed by the MPCA, but which has since been replaced by a new standard leachate test.

Table 2
CHEMICAL CHARACTERISTICS OF METRO PLANT SLUDGE INCINERATOR ASH

Parameter	Concentration October 1977[a] (mg/kg)	Concentration November 1977[b] (mg/kg)
Ag	—	77
Al	—	29,700
Ba	—	166
Ca	—	242,000
Cd	47	50
Co	—	20
Total Cr	2,824	1,180
Cu	2,170	1,820
Fe	—	15,100
Hg	0.11	Negligible
Mg	—	12,600
Mn	—	233
Ni	533	96
Pb	571	60
Zn	2,548	1,070
pH	—	10.75

a Grab sample of ash collected and analyzed by the MWCC.

b Grab sample from ash lagoon collected and analyzed by CH_2M HILL.

The test consisted of filling two glass columns with 100 grams of ash. Distilled water was passed through one column and a one percent nitric acid solution through the other column at rates of one milliliter (ml) per minute. A total of 800 ml was allowed to pass through the columns with the first and the last 200 ml collected and analyzed. Results of this test are presented in Table 3, along with the Minnesota Department of Health (MnDOH) drinking water standards.

Using nitric acid as an elutant gives the maximum metals concentration expected to leach from the ash due to the solubilization of metals at low pH. However, because the ash was to be placed on top of the old landfill and would not be exposed to leachate with a low pH, the MPCA used the distilled water results to analyze potential contamination by the ash.

Extrapolation of leachate test results to the expected leachate from a landfill is difficult. There are a multiplicity of factors affecting a waste's leaching characteristics, both in the test and the landfill. The MPCA analyzed the ash leachate test by comparing the distilled water elutant results to the MnDOH Class A drinking water standards. Since a standard leachate test does not account for changes in leachate quality from passage through the soil or dilution with ground water, the leachate results can be reduced by a factor of ten. This was the approach used by the MPCA in analyzing the results from the leachate test (Ref. 7).

Results from the ash leachate test were submitted to the MPCA for review. The MPCA stated that the test results indicated that metals in the ash were relatively insoluble and should not migrate from the deposited ash (Ref. 8). However, the MPCA did express concern over the concentration of chromium in the leachate test, because 80 to 90 percent was in the toxic hexavalent form. It was determined, although, that under the prevailing conditions at the ash disposal site, that hexavalent chromium would be reduced to the less toxic trivalent chromium (Ref. 9).

Another way to evaluate the potential leachate from the ash is to examine the metal concentration in the ash pond supernatant. Table 4 presents the average concentration of metals in the ash pond supernatant for 1976. Comparing this table with the drinking water standards in Table 3, it can be seen that allowing for attenuation and dilution in the soil, the ash should probably pose no serious threat to the ground water quality.

<u>Ground Water Quality Results and Discussion</u>

Ground water quality monitoring was initiated in June 1977, six months prior to the ash disposal. There was a total of eight wells that were sampled, as previously described and

Table 3
ASH LEACHATE TEST RESULTS

Parameter	Water Elutant First 200 ml (mg/ l)	Water Elutant Last 200 ml (mg/ l)	Acid Elutant First 200 ml (mg/ l)	Acid Elutant Last 200 ml (mg/ l)	MnDOH Drinking Water Standards[a] (mg/l)
Cd	0.01	0.01	0.05	0.10	0.01
Total Cr	6.30	1.05	3.90	4.05	—[b]
Cu	0.85	0.05	0.71	2.20	1
Hg	0.6[c]	0.2[c]	0.8[c]	0.2[c]	—
Ni	0.09	0.05	0.34	0.91	—
Pb	0.06	0.05	0.54	1.16	0.05
Zn	0.03	0.02	0.06	2.82	5
pH	9.45	10.85	—	—	6.5-8.5[d]

a Class A Standards.
b Standard for Cr (VI) is 0.05 mg/l.
c Concentration in ppb.
d Standard for Surface Water Quality.

Source: MWCC; average of results from tests on 6/3, 6/16, and 6/29/77.

Table 4
CHEMICAL CHARACTERISTICS OF ASH POND SUPERNATANT

Parameter	Value (mg/ l)
Cd	<0.02
CN	0.056
Total Cr	0.57
Cu	0.11
Hg	<0.001
Pb	<0.10
Zn	0.11
pH	9.3

Source: MWCC; average of monthly samples for 1976.

shown in Figure 4. Ground water monitoring results for these eight wells are contained in Tables B-4 through B-8 in Appendix B. The ground water analyses were performed in the MWCC Central Laboratory using the U.S. EPA Manual of Methods for Chemical Analysis of Water and Wastes (Ref. 12).

Data on the average ground water quality under the abandoned landfill prior to the ash disposal is presented in Table 5. Comparison of this quality with the MnDOH and U.S. EPA drinking water standards, also contained in Table 5, shows that the ground water will probably not meet drinking water standards without prior treatment.

The ground water quality is very close to the limitations for most of the metals, such as cadmium, chromium, and lead. Values for iron and ammonia exceed the standards or recommendations. In addition, the ground water contains a high concentration of organic compounds, as evidenced by the large chemical oxygen demand (COD). There are no set standards for COD or BOD; but the ground water could contain certain organic chemicals, such as chlorinated hydrocarbons, which do have standards under the National Interim Primary Drinking Water Regulations (Ref. 10).

Results of the ground water monitoring program to date, for wells 101, 102, 104, and 106 are presented in Figures 8 through 23. A summary of apparent changes in ground water quality that were indicated in the monitoring program are given in Table 6. As previously discussed in the section on ground water movement, well 101 is usually located up-gradient of the ash disposal site and is outside of the ash disposal area. Therefore, the ash deposition should not have an impact on the ground water in the region of this well.

Well 102 was found to be located down-gradient for most of the sampling, but is also located outside of the ash disposal site. However, given the ground water flow rate, this monitoring well is probably sampling leachate that has been in contact with the ash.

Well 104 is situated below the ash disposal site with ground water samples taken near the top of the water table. As previously mentioned, this well is probably sampling leachate that has percolated through the ash up to 100 feet up-gradient of the well.

Well 106 was found to be consistently down-gradient of the ash disposal site but due to the low ground water flow rates, it is unlikely that leachate collected from this well has been in contact with the ash.

Table 5
AVERAGE GROUNDWATER CHARACTERISTICS PRIOR TO ASH DISPOSAL

Parameter	Value (mg/ l)	MnDOH Drinking Water Standards[b] (mg/l)
Cd	0.02	0.01
Cn	0.009	0.01
Cr	0.05	—
Cu	0.02	1.0
Fe	0.33	0.3
Hg[a]	0.5	—
Mn	0.67	0.05
Ni	0.07	—
Pb	0.05	0.05
Zn	0.13	5
pH	7.7	6.5 - 8.5
COD	267	—
BOD	16	—
ALKALINITY	1338	—
TKN	135	—
NH_3-N	132	—
NO_3-N	0.75	10

a Concentration in ppb.

b Class A Standards.

Source: MWCC; average results from sampling on 6/16/77 and 6/28/77 at wells 104 through 108.

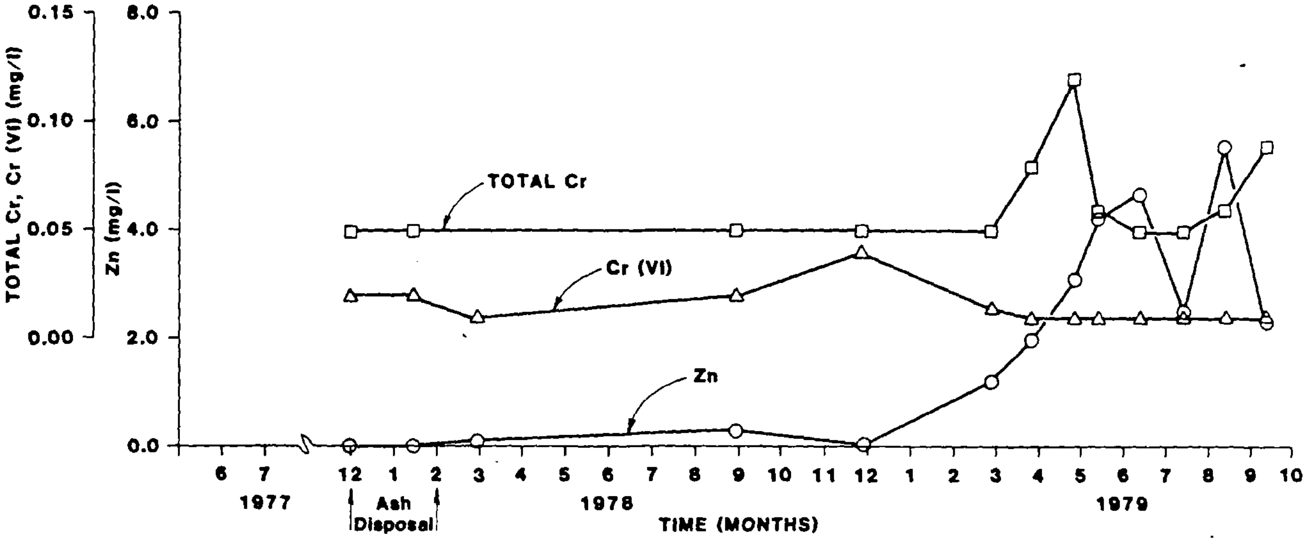


FIGURE 8
CONCENTRATIONS OF TOTAL Cr, Cr (VI) AND Zn IN WELL 101

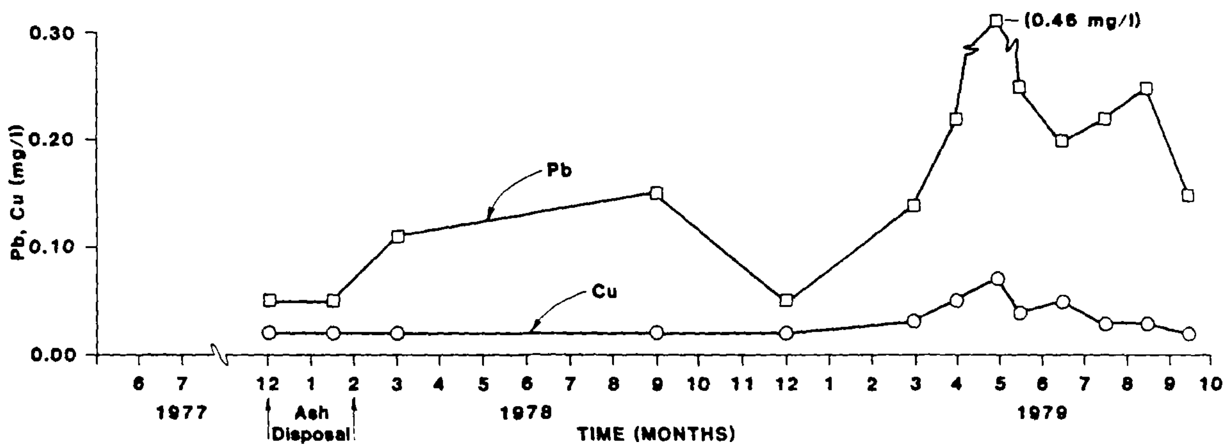


FIGURE 9
CONCENTRATIONS OF Cu AND Pb IN WELL 101

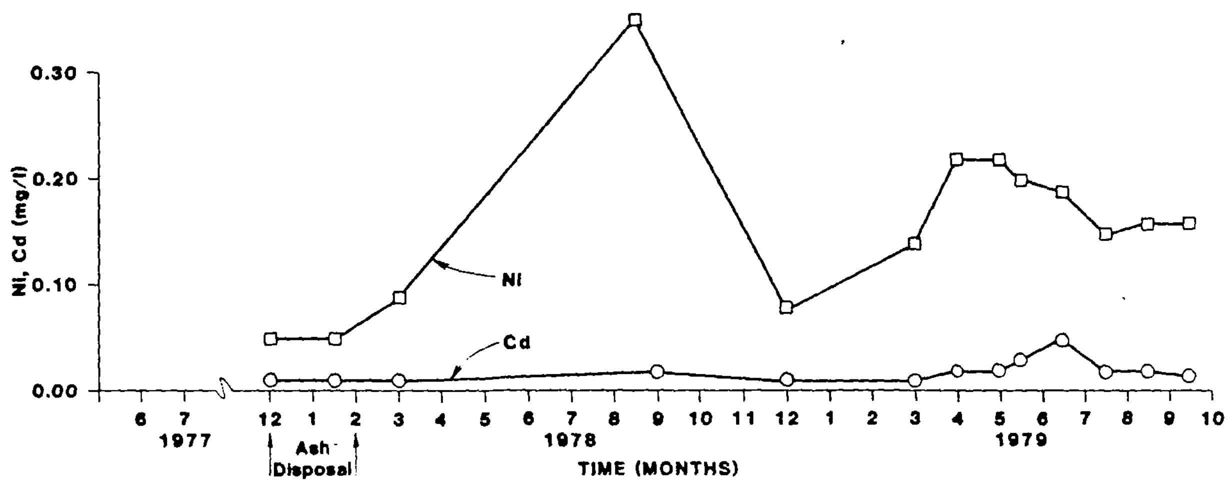


FIGURE 10
CONCENTRATIONS OF Cd AND Ni IN WELL 10

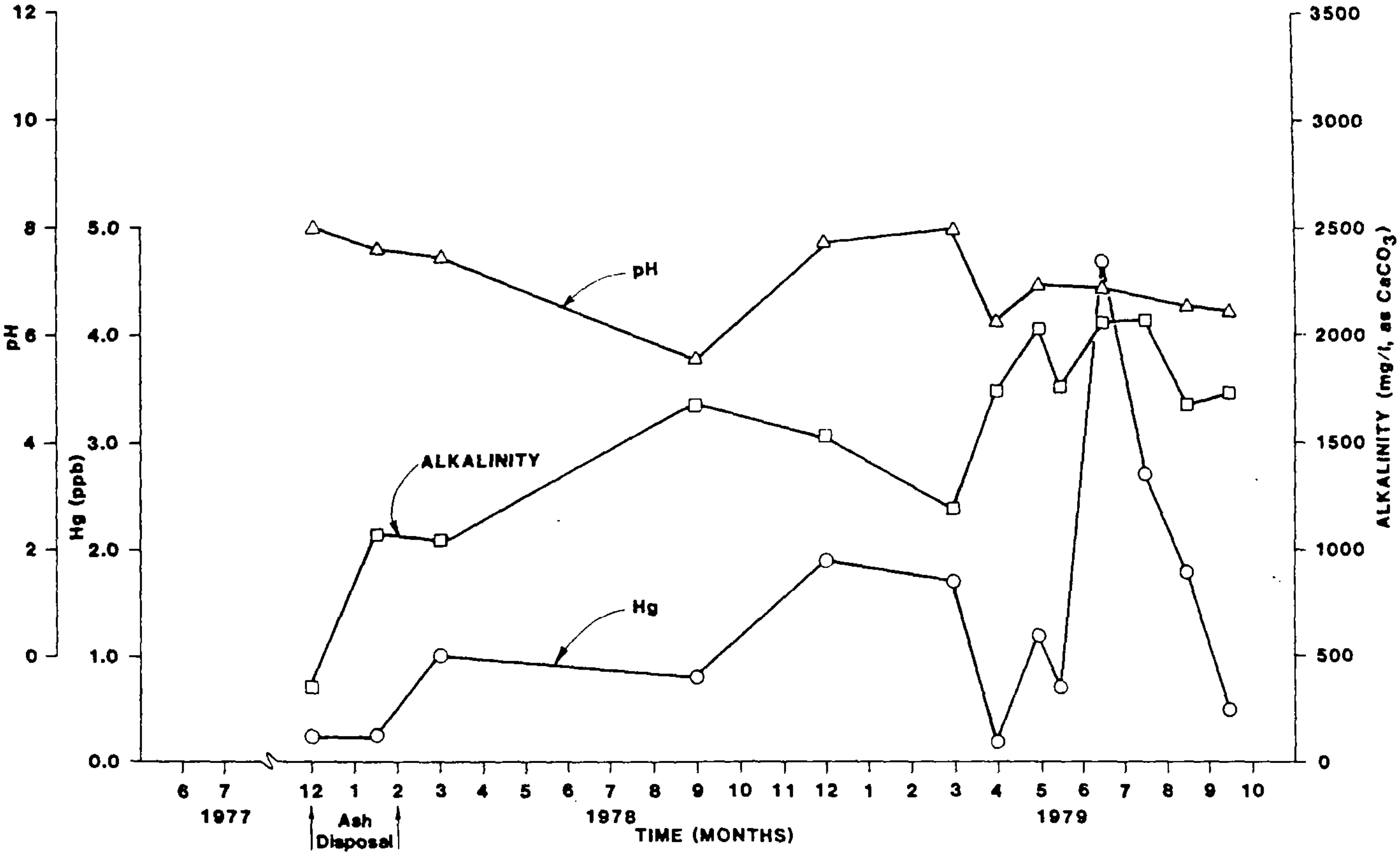


FIGURE 11
ALKALINITY, pH AND Hg CONCENTRATION IN WELL 101

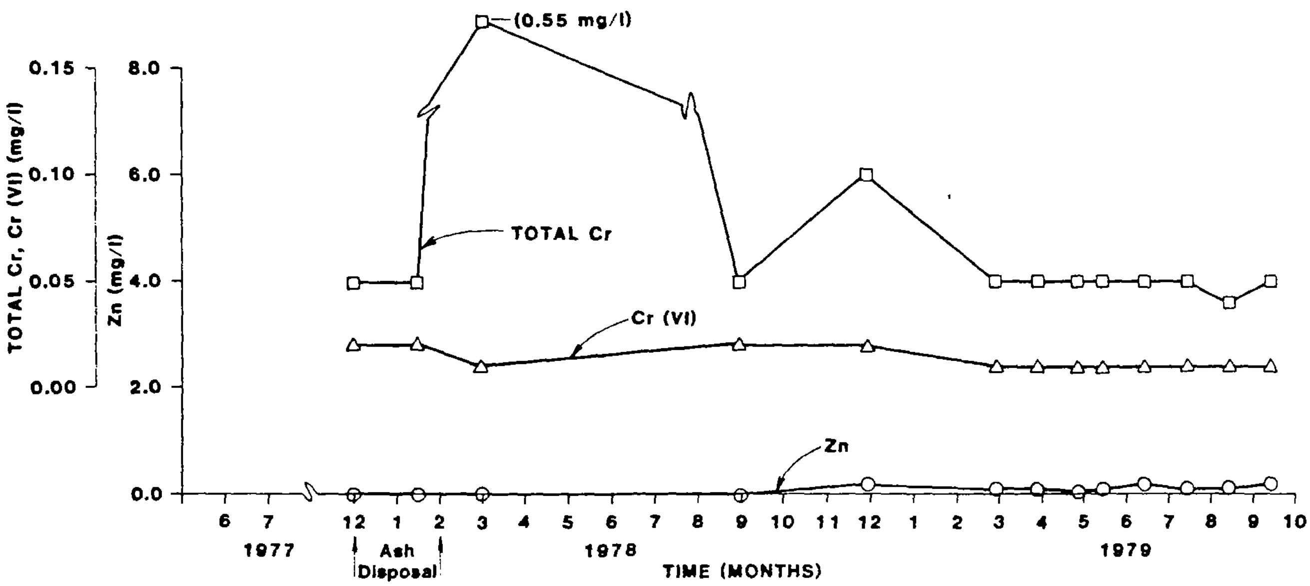


FIGURE 12
CONCENTRATIONS OF TOTAL Cr, Cr (VI), AND Zn IN WELL 102

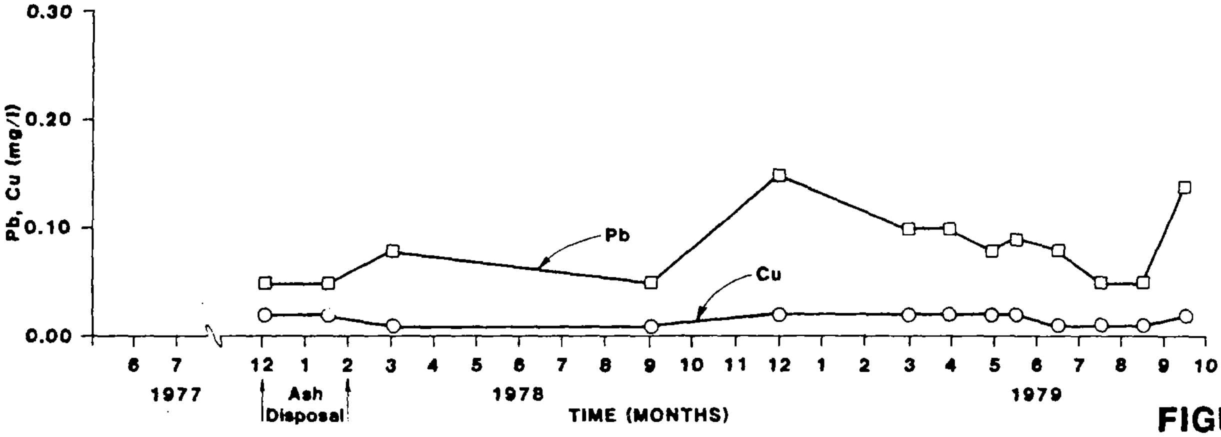


FIGURE 13
CONCENTRATIONS OF Cu AND Pb IN WELL 102

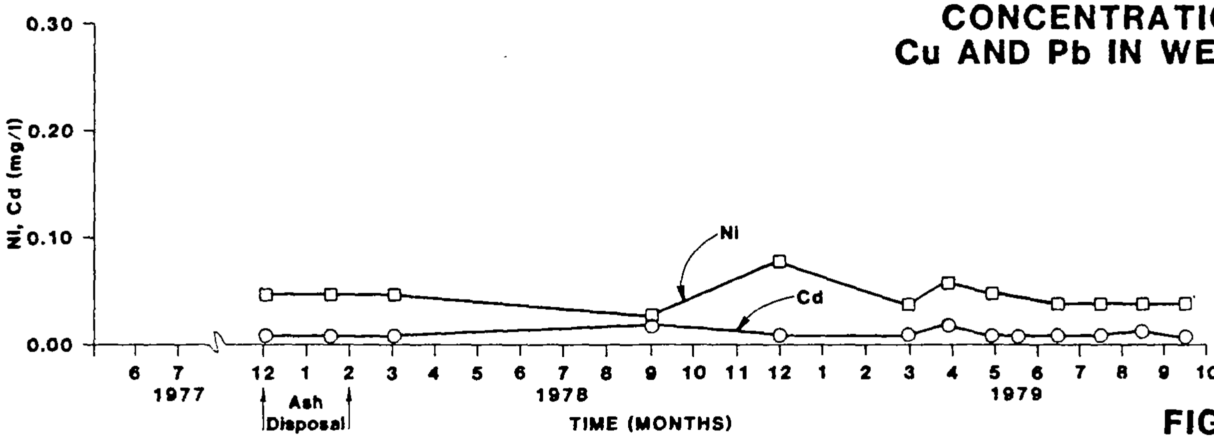


FIGURE 14
CONCENTRATIONS OF Cd AND Ni IN WELL 102

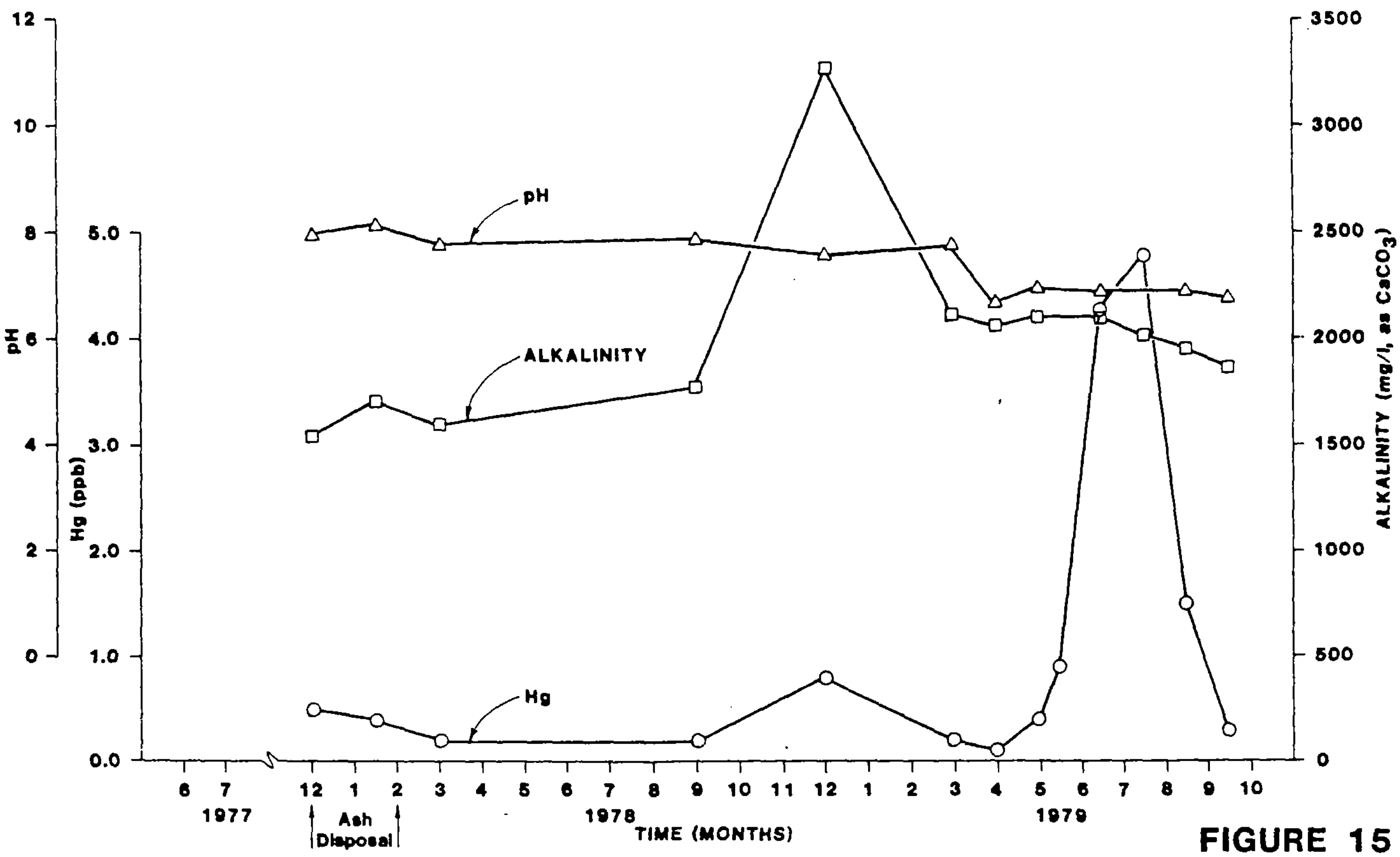


FIGURE 15
ALKALINITY, pH AND Hg CONCENTRATION IN WELL 102

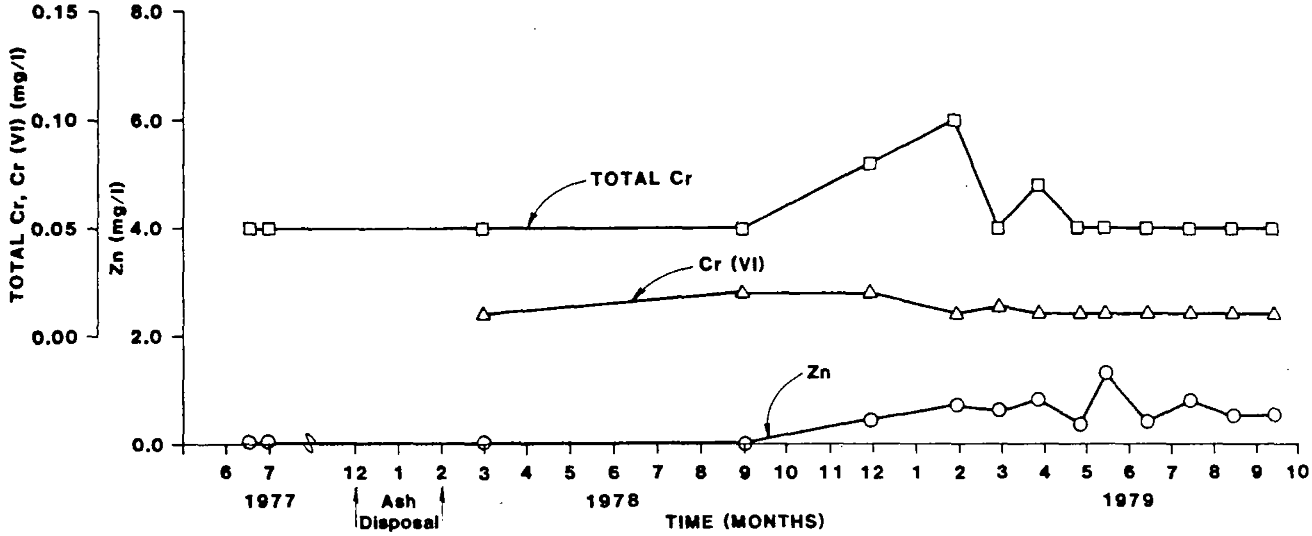


FIGURE 16
CONCENTRATIONS OF TOTAL Cr, Cr (VI) AND Zn IN WELL 104

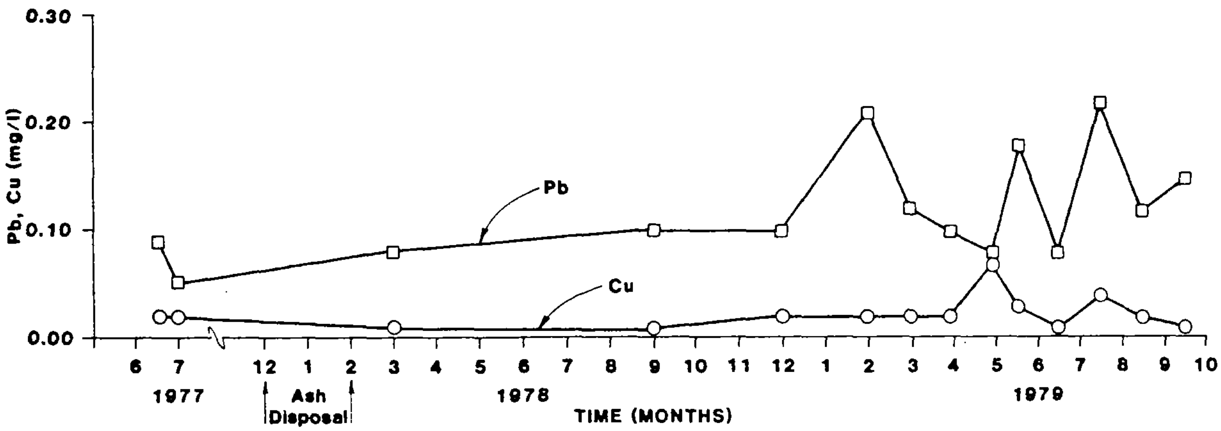


FIGURE 17
CONCENTRATIONS OF Cu AND Pb IN WELL 104

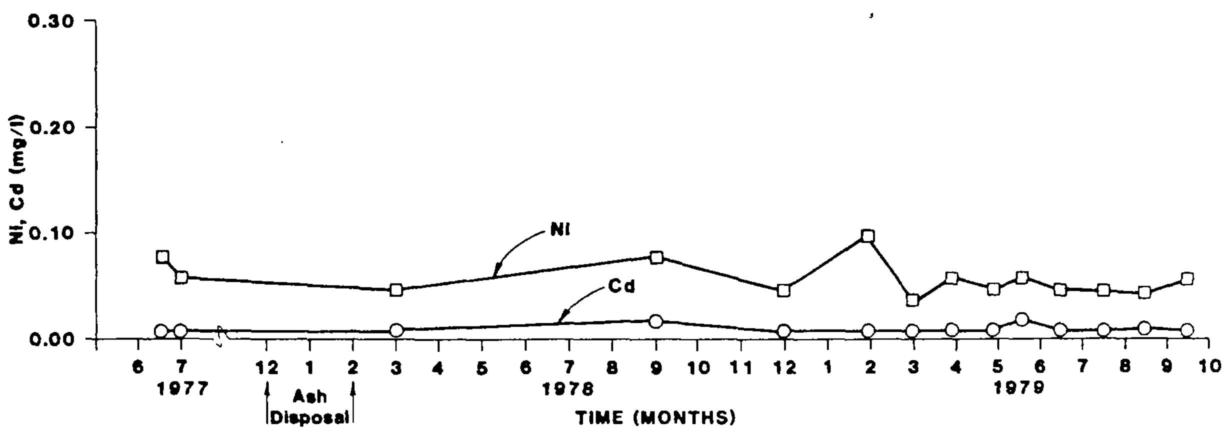


FIGURE 18
CONCENTRATIONS OF Cd AND Ni IN WELL 104

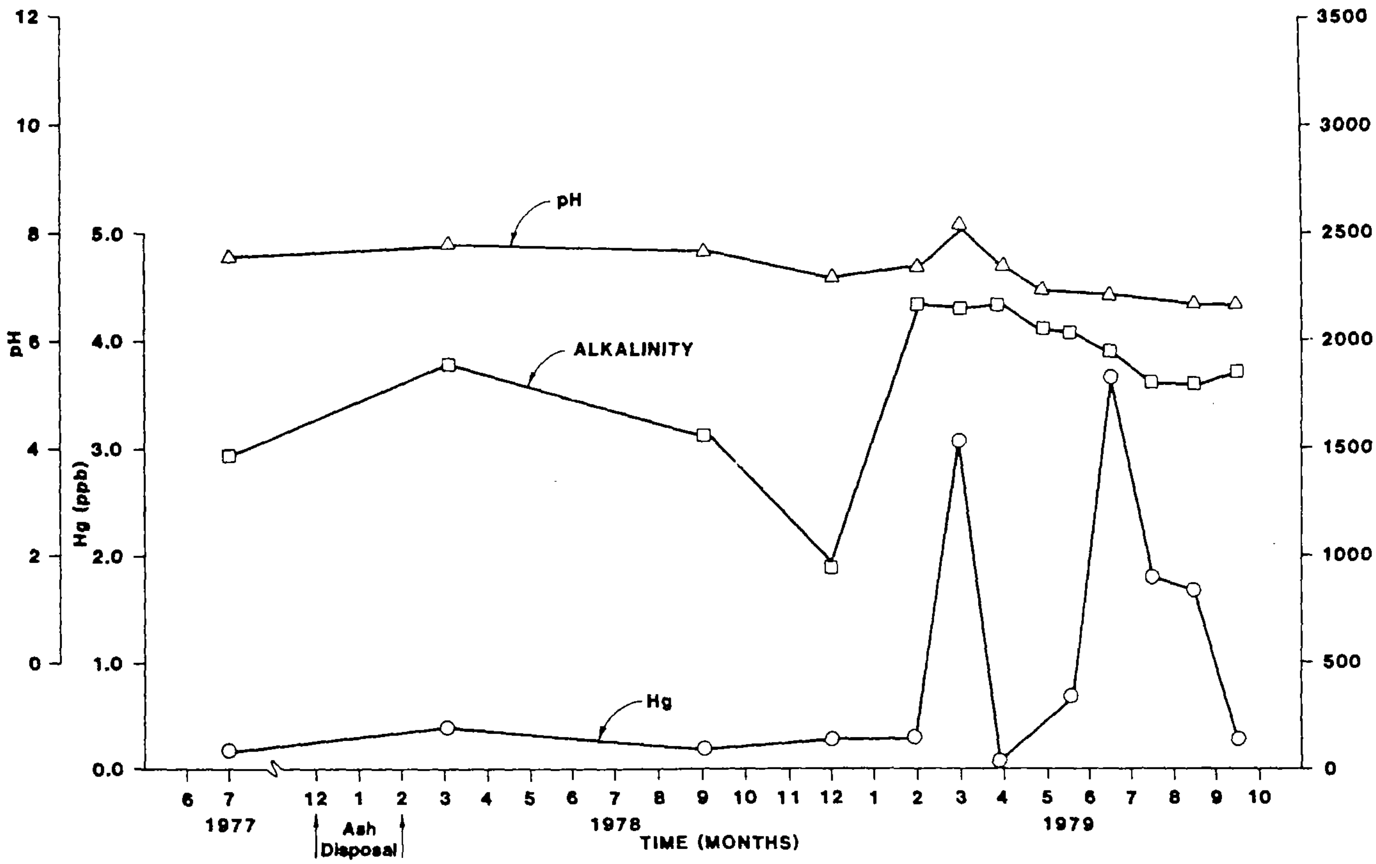


FIGURE 19
ALKALINITY, pH AND Hg CONCENTRATION IN WELL 104

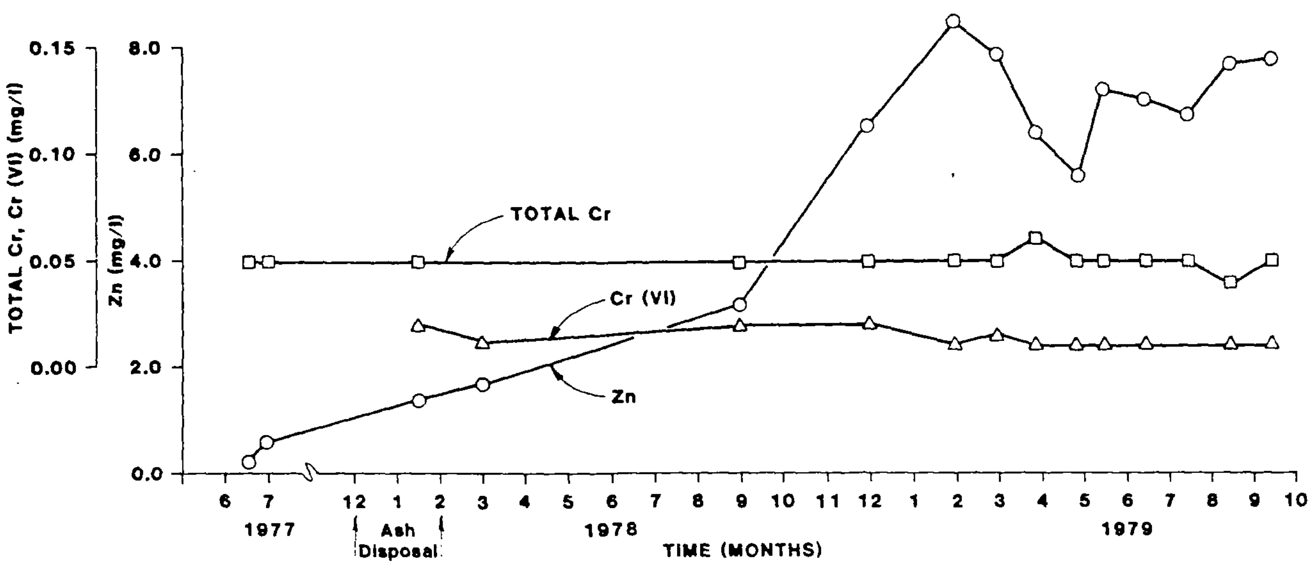


FIGURE 20
CONCENTRATIONS OF TOTAL Cr, Cr (VI), AND Zn IN WELL 106

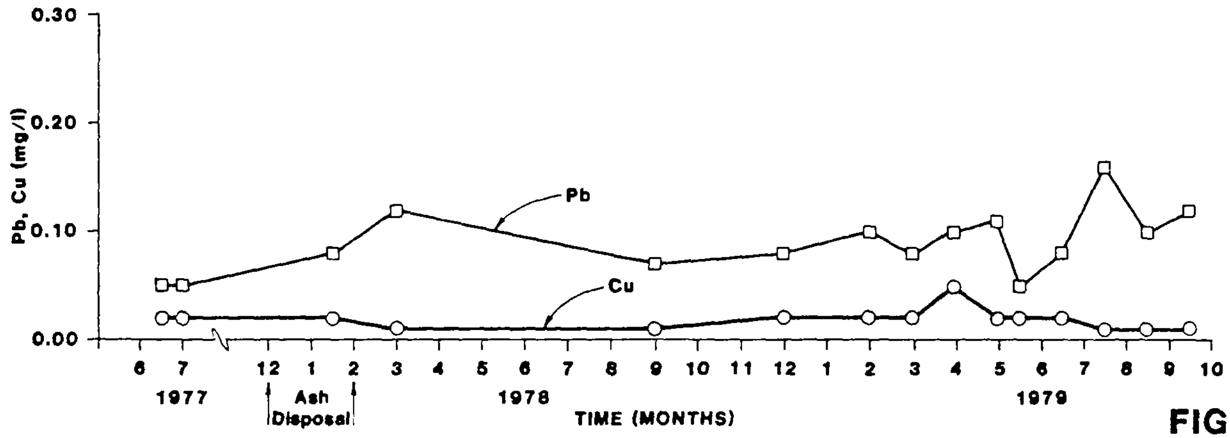


FIGURE 21
CONCENTRATIONS OF Cu AND Pb IN WELL 106

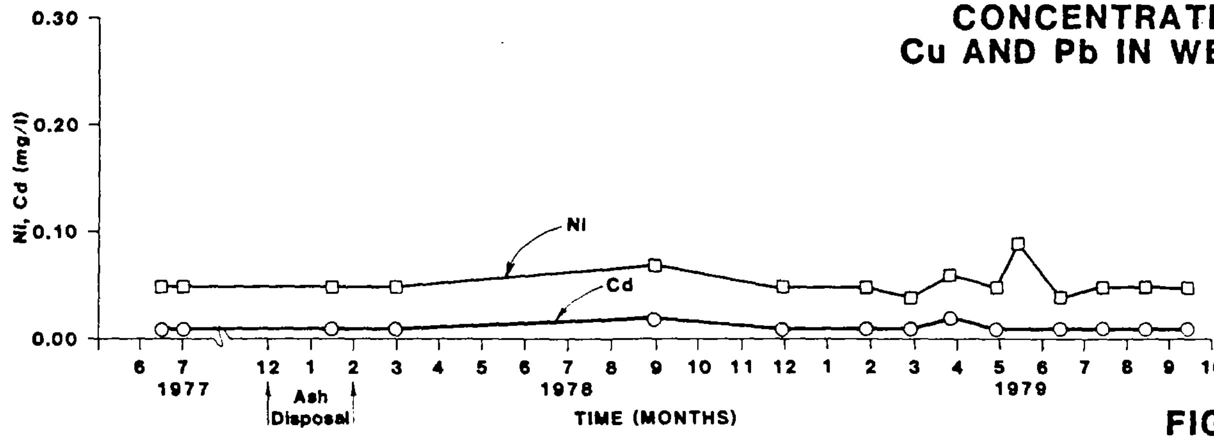


FIGURE 22
CONCENTRATIONS OF Cd AND Ni IN WELL 106

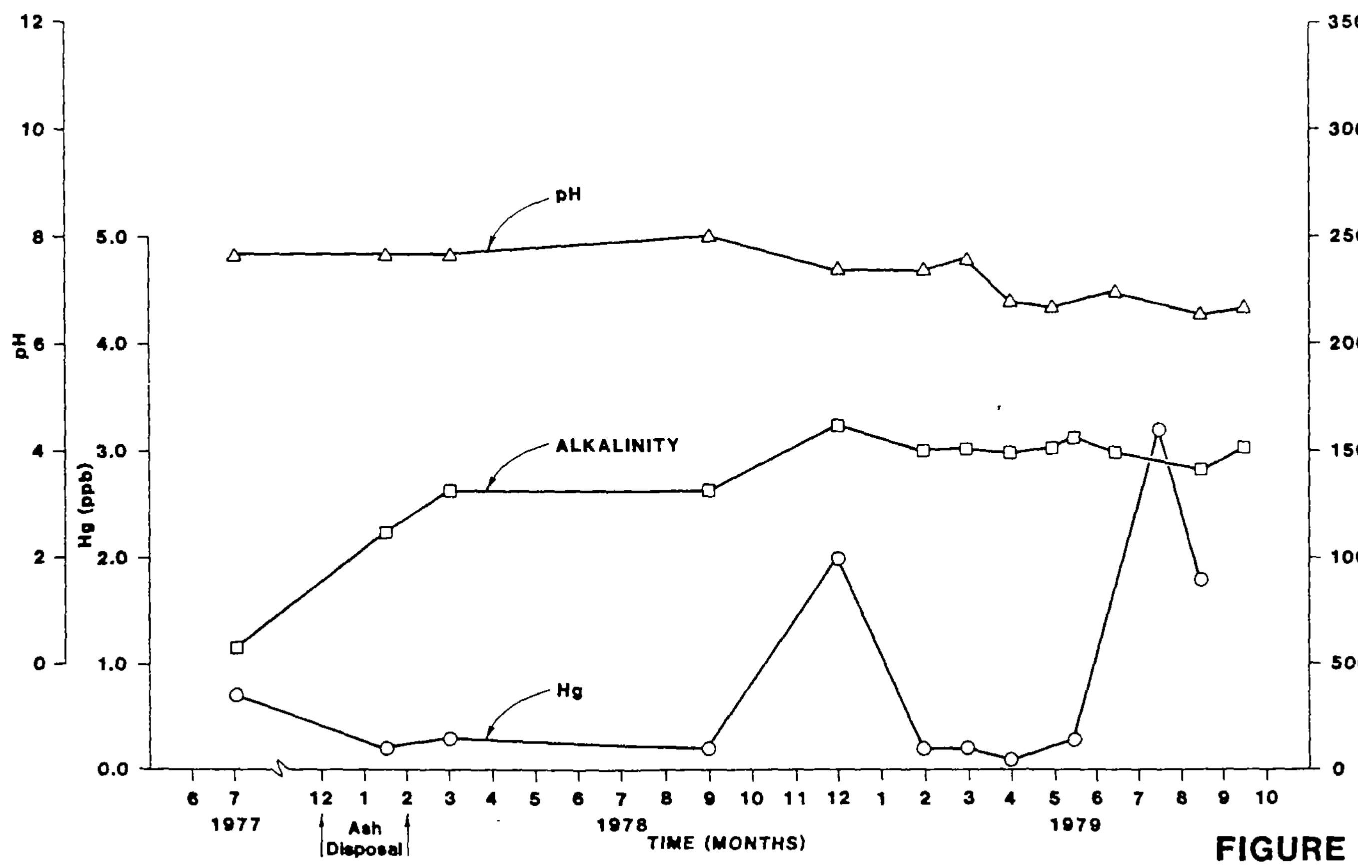


FIGURE 23
ALKALINITY, pH AND Hg CONCENTRATION IN WELL 106

TABLE 6
APPARENT GROUND WATER QUALITY CHANGES FOLLOWING ASH DISPOSAL

PARAMETER	WELL 101	WELL 102	WELL 104	WELL 106
Cd	NO APPARENT CHANGE	NO APPARENT CHANGE	NO APPARENT CHANGE	NO APPARENT CHANGE
TOTAL Cr	NO APPARENT CHANGE	NO APPARENT CHANGE	NO APPARENT CHANGE	NO APPARENT CHANGE
Cr (VI)	NO APPARENT CHANGE	NO APPARENT CHANGE	NO APPARENT CHANGE	NO APPARENT CHANGE
Cu	VARIES SLIGHTLY, BUT BELOW DRINKING WATER STANDARD (1.0 mg/l)[a]	NO APPARENT CHANGE	NO APPARENT CHANGE	NO APPARENT CHANGE
Hg	VARIABLE INCREASE AND DECREASE, BUT BELOW RECOMMENDED DRINKING WATER STANDARD (2.0 mg/l)[b]	INCREASES FOR TWO SAMPLES, BUT THEN DECREASES BELOW RECOMMENDED DRINKING WATER STANDARD (2.0 mg/l)[b]	VARIABLE, BUT GENERALLY BELOW RECOMMENDED DRINKING WATER STANDARD (2.0 mg/l)[b]	VARIABLE. BUT BELOW RECOMMENDED DRINKING WATER STANDARD (2.0 mg/l)[b]
Ni	SLIGHT INCREASE AND THEN DECREASES; NO DRINKING WATER STANDARD	NO APPARENT CHANGE	NO APPARENT CHANGE	NO APPARENT CHANGE
Pb	AT DRINKING WATER STANDARD INITIALLY (0.05 mg/l);[a] INCREASES, BUT THEN DECREASES	SLIGHT VARIABILITY	AT DRINKING WATER STANDARD INITIALLY (0.05 mg/l)[a] AND VARIES PERIODICALLY ABOVE THIS LEVEL	AT DRINKING WATER STANDARD INITIALLY (0.05 mg/l)[a] AND VARIES PERIODICALLY ABOVE THIS LEVEL
Zn	INCREASES, BUT LEVELS OFF BELOW DRINKING WATER STANDARD (5 mg/l)[a]	VARIABLE, BUT INCREASES SLIGHTLY TO A LEVEL BELOW 0.2 mg/l	INCREASES TO A LEVEL OF ABOUT 0.5 mg/l, WHICH IS BELOW DRINKING WATER STANDARD (5 mg/l)[a]	INCREASES TO A LEVEL OF ABOUT 7 mg/l
ALKALINITY	INCREASES, BUT THEN STARTS TO DECREASE	INCREASES, BUT THEN STARTS TO DECREASE	INCREASES, BUT THEN STARTS TO DECREASE	INCREASES TO A CONSTANT LEVEL
pH	VARIABLE, BUT DECREASES FROM ABOUT 8.0 TO 6.5	DECREASE FROM ABOUT 8.0 TO 6.9	DECREASE FROM ABOUT 7.7 TO 6.7	DECREASE FROM ABOUT 7.7 TO 6.7

[a] MnDOH Class A Drinking Water Standards.
[b] Water Quality Standards for Drinking Water (Ref. 13).

The movement of any possible contaminants in the leachate is dependent on the rate of ground water movement and also on the interaction of contaminants with material the ground water moves through, such as soil and refuse. Therefore, the fastest rate contaminants can move is the rate of ground water movement, but due to physical/chemical or oxidation-reduction reactions, the rate is normally less than the rate of ground water movement.

As shown in Figures 8 through 23 and stated in Table 6, there is no apparent change in the concentrations of cadmium, total chromium, and chromium (VI) in the water from wells 101, 102, 104, and 106. The concentration of copper in the water from these wells does not appear to change, except in well 101. The copper concentration rises slightly, but is still below the drinking water standard of 1.0 mg/l.

The mercury concentration varies in the water from the four wells, but is generally below the recommended drinking water standard of 2.0 parts per billion. Water from well 101, which is up-gradient of the ash disposal site, shows the only apparent change in nickel concentration. However, there is no drinking water standard for nickel.

The lead concentration in the ground water is at the drinking water standard prior to ash disposal and varies above this level after the ash disposal in all four wells. It must be noted that this increase in lead concentration occurs in well 101, which is up-gradient of the ash disposal site and well 106, where leachate from the ash should not have migrated to this well within the time period since the ash disposal. This apparent change in the water quality from the four wells also occurs with the zinc concentration. Water from wells 101 and 106, neither of which should be affected by the ash, show greater increases in zinc concentrations than does water from wells 102 and 104.

Assuming that the monitoring well's samples were representative of the ground water and the wells were properly placed in the leachate plume from the ash, the increase in the concentrations of metals in wells 101 and 106 suggests that the apparent ground water quality changes could be from a different source than the ash. Given the complex nature of the soil and landfill system and the interacting factors, it would be difficult to determine what is the exact mechanism and cause of the indicated ground water quality changes, but a few possibilities will be briefly discussed.

Increased solubility of metals could be the result of lowering the pH, reducing conditions, or increasing the concentration of the other competing metals. Soil generally reduces the solubility of most metals by reaction with solid soil surfaces, such as clays, sesquioxides (Fe and Al hydroxides), carbonates, sulfates, and organic matter. Other mechanisms include cation exchange, precipitation, and chelation.

The ground water monitoring data shows that the pH of the ground water is gradually decreasing. The lowering of pH could result in the increase in the solubility of certain metal species that were already contained in the landfill. Taking into account only the effect of the hydroxide species on the solubility of certain divalent metals, lowering the pH by one unit could increase the solubility of metals, such as zinc, by a factor of 100. However, the actual change in solubility would be different due to complex ion formation, competing reactions, adsorption, etc., and would be difficult to predict, given the complex nature of the landfill system.

The decrease in pH appears to occur in well 101 before the other wells. Since well 101 is up-gradient of the ash disposal site and is highly influenced by water in Battle Creek, suggests that acidity could be flowing into the ash area and due to another source than the ash. Surface water from Battle Creek generally moves into the ground water along the old stream bed channel near well 101 and disperses to the north-east, south-east, and south towards wells 102, 104, and 106. This water would be from surface runoff from areas north of the landfill, such as the railroad yard. This surface runoff could contain acidic materials or various metals that were measured in the ground water.

The decrease in pH could also be the result of increased biological activity in the landfill due to fluctuating ground water levels. It should be noted that the ash has a high lime content, which would increase the pH of leachate percolating through the ash.

The pH of the distilled water that was passed through the ash in the leachate test described earlier, was raised to 10.85 (Table 3). The addition of the ash to the top of the landfill should, therefore, have reduced the mobility of metals originating from the landfill. This could be a possible explanation for the lower apparent changes in zinc concentrations in water from wells 102 and 104, compared to wells 101 or 106. However, the pH in all four wells appears to decrease about the same extent.

Another possible source of the indicated ground water quality change is fluctuating ground water levels resulting in oxidation-reduction reactions that could increase the mobility of various metals. Also, since the abandoned landfill contains industrial wastes, chemicals could be originating from this source.

In summary, the increase in certain metals concentrations in wells that should not have been impacted by the ash (wells 101 and 106), suggests that the indicated water quality changes could be due to a source other than the ash. In addition, the magnitude of the apparent change in ground water quality is probably of reduced importance considering that the ground water quality did not meet drinking water standards prior to ash disposal. The mercury and zinc concentrations in water from the wells appear to increase, but generally stay below even the recommended drinking water standards. Given that mercury is measured in the part per billion range, it is also possible that the variation in mercury concentration is due to analytical variations.

REFERENCES

1. Forsberg, F., Department of Public Works, City of St. Paul, Minnesota, Telephone Conversation, October 30, 1979.

2. Metropolitan Council. Leachate Generation Potential from Landfills in the Twin Cities Metropolitan Area: Preliminary Computations and Analysis, Metropolitan Council, St. Paul, Minnesota, March 1978.

3. Fenn, D. G., Hanley, K. J., and De Geare, T. V. Use of the Water Balance Method for Predicting Leachate Generation from Solid Waste Disposal Sites, U. S. Environmental Protection Agency, SW-168, September 1975.

4. National Environmental Research Center, Solid and Hazardous Waste Research Laboratory, Summary Report: Gas and Leachate from Land Disposal of Municipal Solid Waste, Cincinnati, Ohio, July 1974.

5. Zanoni, A. E., "The Environmental Impact of Leachates From Solid Waste Disposal Sites", Prepared for the Solid Waste Disposal Section, Department of Natural Resources, Madison, Wisconsin, July 1973.

6. Soil Exploration Company. Final Report, Phase II Soil and Ground Water Investigation, Proposed Pigs Eye Coal Handling Facilities, St. Paul, Minnesota, Prepared for Toltz, King, Duvall, Anderson, and Associates, St. Paul, Minnesota, February 1974.

7. Brott, B., Solid Waste Division, Minnesota Pollution Control Agency, Roseville, Minnesota, Telephone Conversation, October 25, 1979.

8. Minnesota Pollution Control Agency Board Meeting, Division of Solid Waste Permits Section, Agenda Item IV. 18 (6), "Consideration of Permit for Disposal of Ash from Metropolitan Waste Control Commission Metro Waste Water Treatment Plant Ash Lagoon", November 22, 1977.

9. Hoffmann, M. R. Fate of Chromium Leached from Fly-Ash Residue Dumped on an Old Sanitary Landfill, Report Prepared for the Metropolitan Waste Control Commission and the Minnesota Pollution Control Agency, Undated.

10. U. S. Environmental Protection Agency, Office of Water Supply. National Interim Primary Drinking Water Regulations, EPA-570/9-76-003.

11. U. S. Environmental Protection Agency, Procedures Manual for Ground Water Monitoring at Solid Waste Disposal Facilities, EPA/530/SW-611, August 1977.

12. U. S. Environmental Protection Agency, Manual of Methods for Chemical Analysis of Water and Wastes. Technology Transfer, EPA-625-/6-74-003a, 1976.

13. Quality Criteria for Water. U. S. Environmental Protection Agency, Washington, D. C., July 1976.

14. Chow, V. T., Handbook of Applied Hydrology, McGraw Hill, 1964.

APPENDIX A

PERMIT FOR METROPOLITAN WASTE
CONTROL COMMISSION ASH DISPOSAL SITE

Minnesota Pollution Control Agency

PERMIT FOR METROPOLITAN WASTE CONTROL
COMMISSION ASH DISPOSAL SITE

Pursuant to authorization by the Minnesota Pollution Control Agency, and, as applicable, in accordance with the provisions of Minnesota Statutes, including Chapters 115 and 116 and 473, Agency Regulations SW 1-12 and Agency Rules MPCA 1-13, plans are approved and a permit is hereby granted to the Metropolitan Waste Control Commission for disposal of 150,000 yds^3 of ash from MWCC Metro Wastewater Treatment Plant ash lagoons. The disposal site is located on 39 acres of the N½ of Section 10, T28N, R22W, Ramsey County, City of St. Paul.

The disposal site is described in an application dated September 26, 1977, with plans, specifications, and additional materials received through November 21, 1977, all prepared under the direction of C.R. Payne, P.E., St. Paul, Minnesota. This permit also provides for a monitoring system consisting of five wells located upstream, downstream, and within the disposal site.

SPECIAL CONDITIONS

1. This permit authorizes the disposal of 150,000 yds^3 of incinerated sewage sludge ash only. No other material(s) may be disposed at the site.

2. All possible control measures must be implemented to prevent erosion of ash and soil from the site during and after filling.

3. Prior to disposal of ash, all proposed groundwater monitoring wells must be properly installed and sampled. All wells shall be sampled once per month for two months for background data. Wells must then be monitored on a quarterly basis. In addition to measurement of static water levels, samples shall be collected from all monitoring wells and analyzed for pH, alkalinity, mercury, lead, copper, zinc, nickel, cadmium, ammonia, total chromium, and hexavalent chromium.

1935 West County Road B2, Roseville, Minnesota 55113
Regional Offices • Duluth / Brainerd / Fergus Falls / Marshall / Rochester / Roseville
Equal Opportunity Employer

01502

4. The Metropolitan Waste Control Commission must submit a report, on or before September 1, 1978, analyzing alternative uses and interim methods for disposal of ash materials for the period to December 31, 1981. The environmental impacts of any alternative uses and disposal methods must be adequately addressed in the report.

GENERAL CONDITIONS

1. This permit shall not release the permittee from any liability or obligation imposed by Minnesota Statutes or local ordinances and shall remain in force subject to all conditions and limitations now or hereafter imposed by law. This permit shall be permissive only and shall not be construed as estopping or limiting any claims against the permittee, its agents, contractors or assigns, nor as estopping or limiting any legal claims of the State against the permittee, its agents, contractors or assigns for damage to State property, or for any violation of the terms of this permit.

2. The use of the disposal site shall be in accord with and limited to the disposal of ash material described in the plans and permit application and associated material on file with the Agency.

3. The disposal site shall be operated at all times in accordance with the provisions of this permit and any applicable statute, rule, regulation, standard, or order.

4. No major alteration or addition to the disposal site that would materially alter the method or effect of disposal shall be made without the written consent of the Agency.

5. This permit may not be assigned or transferred by the holder without the approval of the Agency. The Agency may, in its discretion, hold a hearing on any request to assign or transfer the permit.

6. The permit holder shall allow the Agency or any authorized employee or agent of the Agency to enter upon any property, public or private for the purposes of examining and copying records, conducting inspections, surveys, investigations, monitoring, sampling and otherwise obtaining necessary information pertaining to the construction, operation and environmental effect of the disposal facility, control equipment and control materials.

7. This permit shall not prevent the future adoption by the Agency of any rule, regulation, standard or order more stringent than, those now in existence or prevent the enforcement of such rule, regulation, standard or order against the permit holder.

Bruce W. Brott, P.E., Acting Chief	Robert A. Silvagni
Permits Section	Director
Division of Solid Waste Division	Division of Solid Waste

Permit No. SW-189
Dated: November 22, 1977

1110155

DIVISION OF SOLID WASTE

MINNESOTA POLLUTION CONTROL AGENCY

STATE OF MINNESOTA

PERMIT FOR CONSTRUCTION AND OPERATION OF A SOLID WASTE DISPOSAL SYSTEM HAS BEEN ISSUED

ISSUED TO

METROPOLITAN WASTE CONTROL COMMISSION

Name of Municipality, Corporation, Company, Person or Institution

Permit No. SW-189

SUBJECT TO CONTINUED CONFORMANCE WITH THE MINNESOTA POLLUTION CONTROL AGENCY'S SOLID WASTE DISPOSAL REGULATIONS

By __________
Director, Division of Solid Waste

By __________
Chief, Section of Standards, Surveys and Plan Review

Date November 22, 1977

01504

APPENDIX B

GROUND WATER MONITORING WELL CONSTRUCTION AND RESULTS

TABLE B-1
MONITORING WELL CONSTRUCTION DETAILS

WELL NO.	DATE INSTALLED	REPORTED DEPTH BELOW LAND SURFACE			MEASURED TOTAL DEPTH 10/12/79 (FT)	TOP OF CASING (M.S.L.)	GRADE ELEVATION (M.S.L.)	REMARKS
		TOTAL (FT)	CASING (FT)	FINISH (FT)				
101	11/30/77	24.0	21′-2″ PVC	3′ PVC SCREEN	23.1	705.80	702.8	PACKED WITH SAND TO 5 FT BELOW GRADE; UPPER 5 FT GROUTED
102	11/30/77	20.0	17′-2″ PVC	3′ PVC SCREEN	19.1	706.76	703.2	SAME CONSTRUCTION AS WELL 101
104	10/25/73	44	15′-2″ PVC	OPEN HOLE	13.7	703.36	700.2	DRILLED TO 44 FT ON 9/3/73 CASED ON 10/25/73 BY SOIL EXPLORATION CO.
106	10/73	—	—	—	19.0	702.52	699.7	INSTALLED BY SOIL EXPLORATION CO.
107	10/73	—	—	—	19.2	701.52	698.9	INSTALLED BY SOIL EXPLORATION CO.
108	10/25/73	59.7	21′-2″ PVC	OPEN HOLE	19.0	704.21	701.7	DRILLED TO 59.7 FT ON 9/14/73 CASED ON 10/25/73 BY SOIL EXPLORATION CO.

TABLE B-2
WELL NUMBERING SYSTEMS AT PIGS EYE LANDFILL

CH2M-HILL 10/79	MPCA 6/79-	MWCC 3/78-6/79	MWCC 12/77-3/78	MWCC 6/77-12/77	SOIL EX. CO. 10/73
101	60124	1	1	—	—
102	60220	2	2	—	—
103	60324	3	3	—	—
104	60418	4	—	1	P-110D
105	—	—	4	2	P-110E
106	60524	5	5	4	P-120
107	—	—	—	3	P-121
108	—	—	—	5	P-109

1110151

01506

TABLE B-3
MONITORING WELL WATER LEVEL DATA

WELL NO. (CH2M-HILL)	DATE	TOP ELEVATION OF CASING (M.S.L.)[a]	DEPTH TO WATER TABLE FROM TOP OF CASING (FT)	WATER LEVEL ELEVATION (FT)	LAND SURFACE ELEVATION (M.S.L.)[a]
101	10/12/79[b]	705.80	15.38	690.42	702.8
	9/79	C	11.5	694.3	C
	8/79	O	11.5	694.3	O
	7/79	N	14.0	691.8	N
	6/79	S	11.5	694.3	S
	5/79	T	12.0	693.8	T
	4/79	A	12.0	693.8	A
	3/79	N	12.0	693.8	N
	11/30/77[c]	T	—	690.1	T
102	10/12/79[b]	706.76	14.67	692.09	703.2
	9/79	C	15.2	691.6	C
	8/79	O	15.0	691.8	O
	7/79	N	11.0	695.8	N
	6/79	S	14.5	692.3	S
	5/79	T	13.0	693.8	T
	4/79	A	13.0	693.8	A
	3/79	N	15.0	691.8	N
	11/30/77[c]	T	—	691.1	T
104	10/12/79[b]	703.36	13.44	689.92	700.2
	9/79	C	11.7	691.7	C
	8/79	O	11.0	692.4	O
	7/79	N	11.0	692.4	N
	6/79	S	11.0	692.4	S
	5/79	T	11.0	692.4	T
	4/79	A	8.8	694.6	A
	3/79	N	11.5	691.9	N
	12/77	T	—	683.0	T
106	10/12/79[b]	C 702.52	11.52	691.00	C 699.7
	9/79	O	12.0	690.5	O
	8/79	N	12.5	690.0	N
	7/79	S	11.7	690.8	S
	6/79	T	11.5	691.0	T
	5/79	A	10.0	692.5	A
	4/79	N	9.5	693.0	N
	3/79	T	15.0	687.5	T
108	10/12/79[b]	704.21	13.05	691.16	701.7
107	10/12/79[b]	701.52	11.93	689.59	698.9

[a] mean sea level datum.

[b] measured by CH2M HILL.

[c] measured by Soil Exploration Co.

Source: MWCC, unless otherwise noted.

TABLE B-4
GROUND WATER QUALITY DATA FROM WELL 101

DATE

		12/77	1/78	3/78	9/78	12/78	1/31/79[1]	2/28/79	3/26/79	4/26/79	5/17/79	6/79	7/79	8/79	9/79
1.3	Cu (mg/l)	<0.02	<0.02	0.02	0.02	0.02	0.20	0.03	0.05	0.07	0.04	0.05	0.03	0.03	0.02
0.15	Ni (mg/l)	<0.05	<0.05	0.09	0.35	0.08	0.52	0.14	0.22	0.22	0.20	0.18	0.15	0.16	0.16
0.02	Pb (mg/l)	<0.05	0.05	0.11	0.15	0.05	0.40	0.14	0.22	0.46	0.25	0.20	0.22	0.25	0.15
	Zn (mg/l)	0.03	<0.05	0.10	0.30	0.07	9.60	1.27	2.00	3.10	4.20	4.70	2.50	5.60	2.3
.005	Cd (mg/l)	<0.01	<0.01	<0.01	0.02	<0.01	0.02	0.01	0.02	0.02	0.03	0.05	0.02	0.02	0.015
	Cr (Total) (mg/l)	<0.05	<0.05	2.60	<0.05	<0.05	0.37	0.05	0.08	0.12	0.06	0.05	<0.05	0.06	0.09
0.120	Cr (VI) (mg/l)	<0.02	<0.02	<0.01	<0.02	0.04	<0.01	0.014	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
3.0	Hg (ppb)	<0.2	<0.2	1.0	0.8	1.9	0.8	1.7	0.2	1.2	0.7	4.7	2.7	1.8	0.5
	NH_3–N (mg/l)	15	40	41	200	180	200	180	175	175	135	165	155	160	
	TKN (mg/l)			44	200										
	ALK (mg/l $CaCO_3$)	340	1096	1031	1697	1532	1667	1198	1743	2028	1750	2060	2073	1658	1733
	Total P (mg/l)			<0.2	<0.2										
	pH	8.0	7.6	7.5	5.6	7.9	6.8	8.0	6.3	7.0		6.9		6.6	6.5

1 Samples collected were rusty brown in color probably due to sample contamination

TABLE B-5
GROUND WATER QUALITY DATA FROM WELL 102

DATE

		12/77	1/78	3/78	9/78	12/78	1/31/79[1]	2/28/79	3/26/79	4/26/79	5/17/79	6/79	7/79	8/79	9/79
1.3	Cu (mg/l)	<0.02	<0.02	0.01	<0.01	<0.02	1.40	0.02	0.02	0.02	0.02	<0.01	0.01	<0.01	0.02
0.15	Ni (mg/l)	<0.05	<0.05	0.05	0.03	0.08	0.66	0.04	0.06	0.05		0.04	0.04	0.04	0.04
.02	Pb (mg/l)	<0.05	<0.05	0.08	<0.05	0.15	5.5	0.10	0.10	0.08	0.09	0.08	0.05	0.05	0.14
	Zn (mg/l)	<0.02	<0.05	0.02	<0.05	0.25	9.30	0.12	0.11	0.08	0.14	0.21	0.16	0.11	0.25
.005	Cd (mg/l)	<0.01	<0.01	<0.01	0.02	<0.01	0.08	<0.01	0.02	0.01	0.01	<0.01	<0.01	0.015	0.01
	Cr (Total) (mg/l)	<0.05	<0.05	0.55	<0.05	0.10	0.60	<0.05	<0.05	<0.05	0.05	<0.05	<0.05	<0.04	<0.05
.120	Cr (VI) (mg/l)	<0.02	<0.02	<0.01	<0.02	0.02	<0.01	0.014	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
3.0	Hg (ppb)	0.5	0.4	0.2	0.2	0.8	5.8	0.2	<0.1	0.4	0.9	4.3	4.8	1.5	0.3
	NH_3–N (mg/l)	205	220	170	250	220	250	235	230	250	205	240	270	250	
	TKN (mg/l)			175	260										
	ALK (mg/l $CaCO_3$)	1544	1711	1607	1785	3275	2198	2128	2057	2056	2105	2103	2020	1956	1868
	Total P (mg/l)			<0.2	<0.2										
	pH	8.0	8.2	7.8	7.9	7.6	7.5	7.8	6.7	7.0		6.9		6.9	6.8

1 Samples collected were rusty brown in color probably due to sample contamination

1110148

01509

TABLE B-6
GROUND WATER QUALITY DATA FROM WELL 104

DATE

		6/16/77	6/28/77	3/78	9/78	12/78	1/31/79	2/28/79	3/26/79	4/26/79	5/17/79	6/79	7/79	8/79	9/79
1.3	Cu (mg/l)	0.02	0.02	0.01	0.01	<0.02	0.02	0.02	0.02	0.07	0.03	0.01	0.04	0.02	0.01
0.15	Ni (mg/l)	0.08	0.06	0.05	0.08	0.05	0.10	<0.04	0.06	0.05	0.06	0.05	<0.04	0.04	0.06
.02	Pb (mg/l)	0.09	0.05	0.08	0.10	0.10	0.21	0.12	0.10	0.08	0.18	0.08	0.22	0.12	0.15
	Zn (mg/l)	0.05	0.03	0.02	<0.05	0.45	0.71	0.64	0.80	0.38	1.33	0.39	0.76	0.55	0.48
.005	Cd (mg/l)	0.01	0.01	<0.01	0.02	<0.01	0.01	<0.01	0.01	0.01	0.02	0.01	0.01	<0.01	0.01
	Cr (Total) (mg/l)	0.05	0.05	<0.05	<0.05	0.08	0.10	<0.05	0.07	0.05	<0.05	<0.05	<0.05	<0.05	<0.05
.120	Cr (VI) (mg/l)			<0.01	<0.02	<0.02	<0.01	0.014	<0.010	<0.010	<0.010	<0.01	<0.01	<0.01	<0.01
3.0	Hg (ppb)		0.2	0.4	<0.2	0.3	0.3	3.1	<0.1		0.7	3.7	1.8	1.7	0.3
	NH_3–N (mg/l)		160.0	150	205	160	175	180	155	165	150	195	225	180	
	TKN (mg/l)		165.0	165	210										
	ALK (mg/l $CaCO_3$)		1470	1896	1578	951	2177	2165	2185	2061	2041	1968	1807	1802	1860
	NO_3–N (mg/l)		0.74												
	NO_2–N (mg/l)		0.01												
	PO_4-P (mg/l)		0.08	<0.2	<0.2										
	pH		7.6	7.8	7.7	7.2	7.4	8.2	7.4	7.0		6.9		6.7	6.7
	COD (mg/l)		312												
	BOD (mg/l)		8.0												
	Fe (mg/l)		0.12												
	Mn (mg/l)		0.39												

1110147

01510

TABLE B-7
GROUND WATER QUALITY DATA FROM WELL 106

DATE

		6/16/77	6/28/77	1/78	3/78	9/78	12/78	1/31/79	2/28/79	3/26/79	4/26/79	5/17/79	6/79	7/79	8/79	9/79
1.3	Cu (mg/l)	0.02	0.02	<0.02	0.01	0.01	<0.02	<0.02	0.02	0.05	0.02	0.02	0.02	0.01	0.01	0.01
0.15	Ni (mg/l)	0.05	0.05	<0.05	0.05	0.07	0.05	0.05	<0.04	0.06	0.05	0.09	0.04	0.05	0.05	0.05
.02	Pb (mg/l)	0.05	0.05	0.08	0.12	0.07	0.08	0.10	0.08	0.10	0.11	<0.05	0.08	0.16	0.10	0.12
	Zn (mg/l)	0.23	0.63	1.40	1.75	3.20	6.50	8.50	7.90	6.40	5.60	7.20	7.00	6.70	7.7	7.8
.005	Cd (mg/l)	0.01	0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	0.02	0.01		0.01	<0.01	<0.01	0.01
	Cr (Total) (mg/l)	0.05	0.05	<0.05	0.52	<0.05	<0.05	<0.05	<0.05	0.06	<0.05	<0.05	<0.05	<0.05	<0.04	<0.05
.120	Cr (VI) (mg/l)			<0.02	<0.01	<0.02	<0.02	<0.01	<0.014	0.010	<0.010	<0.010	<0.01		<0.01	<0.01
3.0	Hg (ppb)		0.7	<0.2	0.3	<0.2	2.0	<0.2	<0.2	0.1		0.3		3.2	1.8	
	NH_3-N (mg/l)		7.0	10	5.0	2.0	50.0	15	14.0	10.0	9.5	6.0	11.0	10.0	8.0	
	TKN (mg/l)		8.0		9.5	10.0										
	ALK (mg/l $CaCO_3$)		565	1118	1315	1318	1625	1504	1511	1495	1551	1553	1495		1414	1512
	NO_3-N (mg/l)		0.24													
	NO_2-N (mg/l)		0.01													
	PO_4-P (mg/l)		0.26		<0.2	<0.2										
	pH		7.7	7.7	7.7	8.0	7.4	7.4	7.6	6.8	6.7		7.0		6.6	6.7
	COD (mg/l)		43													
	BOD (mg/l)		10													
	Fe (mg/l)		0.62													
	Mn (mg/l)		1.12													

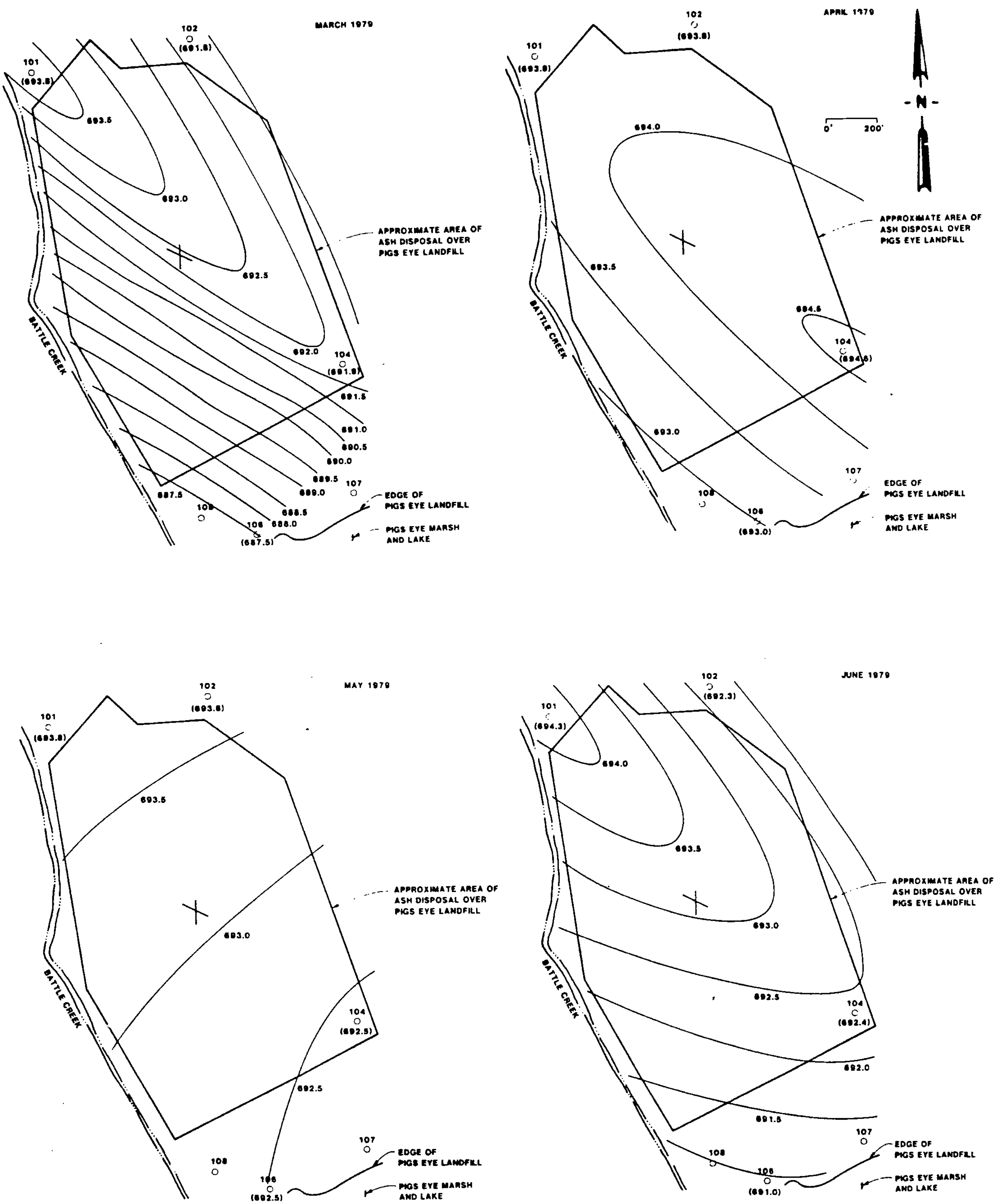
1110146

01511

TABLE B-8
GROUND WATER QUALITY DATA FROM WELLS 103, 105, 107, and 108

		Well 103		Well 105			Well 107		Well 108	
		12/77	1/78	6/16/77	6/28/77	12/77	6/16/77	6/28/77	6/16/77	6/28/77
1.3	Cu (mg/l)	<0.02	<0.02	0.02	0.02	<0.02	0.03	0.05	0.02	0.02
0.15	Ni (mg/l)	<0.05	<0.05	0.05	0.05	<0.05	0.09	0.06	0.08	0.11
0.02	Pb (mg/l)	<0.05	<0.05	0.05	0.05	<0.05	0.06	0.05	0.05	0.05
	Zn (mg/l)	0.08	<0.05	0.05	0.03	<0.02	0.05	0.04	0.04	0.16
.005	Cd (mg/l)	<0.01	<0.01	0.01	0.01	<0.01	0.01	0.01	0.01	0.01
	Cr (Total) (mg/l)	<0.05	<0.05	0.05	0.05	<0.05	0.05	0.05	0.05	0.05
.120	Cr (VI) (mg/l)	<0.02	<0.02			<0.02				
3.0	Hg (ppb)	0.4	0.5		0.3	<0.2		0.3		0.8
	NH_3-N (mg/l)	120	165	210.0		135		280.0		5.0
	TKN (mg/l)			210.0				280.0		9.0
	ALK (mg/l $CaCO_3$)	1090	1464	1710		1043		1745		1200
	NO_3-N (mg/l)			1.51				0.78		0.47
	NO_2-N (mg/l)			0.04				0.02		0.03
	PO_4-P (mg/l)			0.09				0.10		0.14
	pH	7.7	8.1	7.8		7.6		7.9		7.6
	COD (mg/l)			280				465		235
	BOD (mg/l)			7.0				47		7.8
	Fe (mg/l)				0.40			0.30		0.23
	Mn (mg/l)				0.38			0.14		1.42

01513



○ WELLS WITH WATER LEVEL AND/OR WATER QUALITY DATA

DATUM: MEAN SEA LEVEL

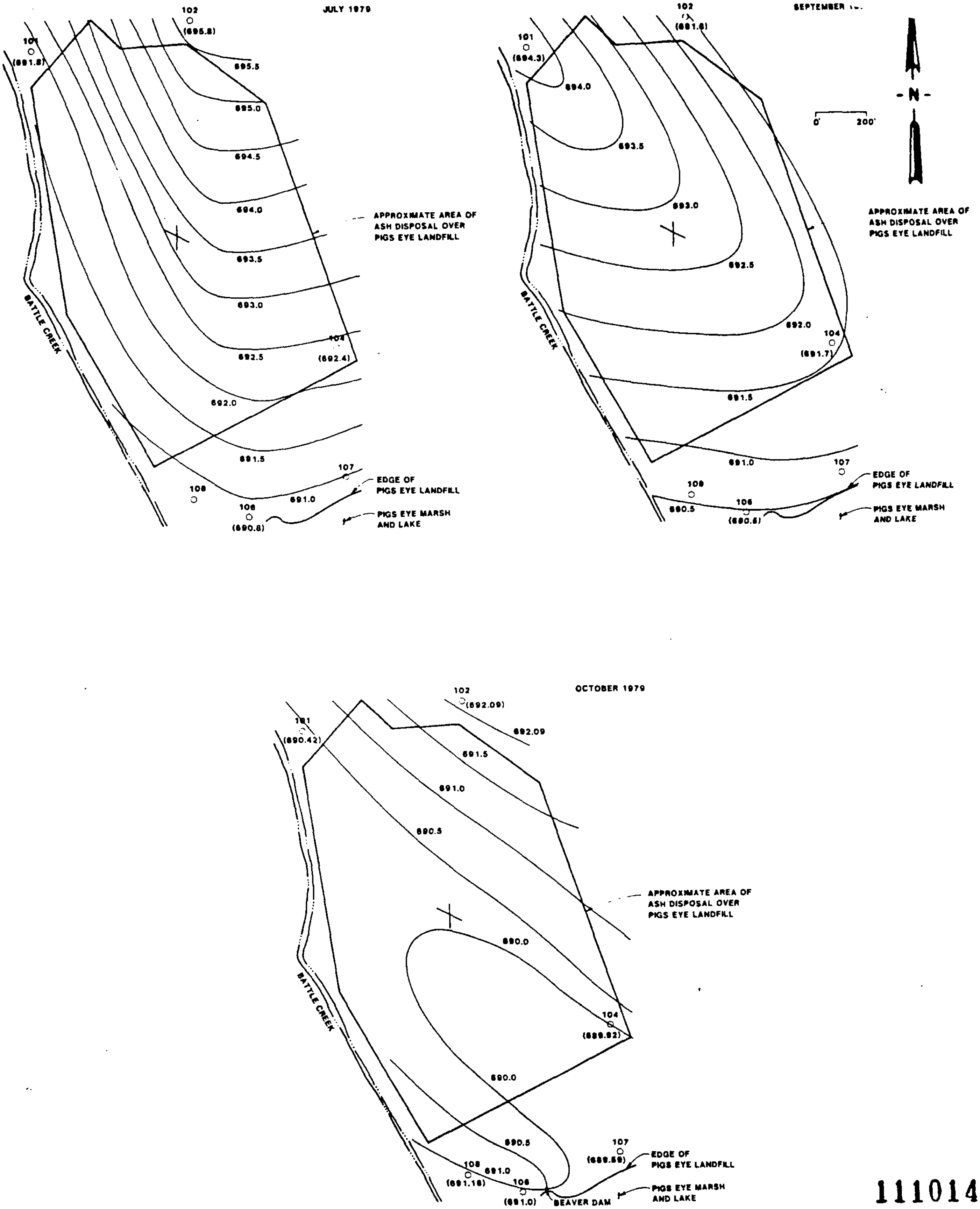
MEASURED WATER LEVELS IN PARENTHESIS

FIGURE B-1

APPROXIMATE WATER TABLE CONTOURS: MARCH - JUNE 1979

1110144

01514



1110143

○ WELLS WITH WATER LEVEL AND/OR WATER QUALITY DATA

DATUM: MEAN SEA LEVEL

MEASURED WATER LEVELS IN PARENTHESIS

FIGURE B-2
APPROXIMATE WATER TABLE CONTOURS : JULY - OCTOBER 1979

01515

COUNTY Ramsey

MINNESOTA POLLUTION CONTROL AGENCY
Division of Solid Waste

Complaint and Investigation Sheet

Date 8/16/78 ~~Complaint Taken~~ Investigation By: Comeau

Location: Township Pigs Eye - MWCC Section: ?

Description: MWCC is (& probably have for years) dumping grit & screenings ~ 15' west of ash ponds; several hundred yds³; mostly silty sand w/ tampon holders, condomes etc — stinks; alot of flies; some red material? some white material? Appears to be some leachate seeping to adjacent low area (Wetland?)

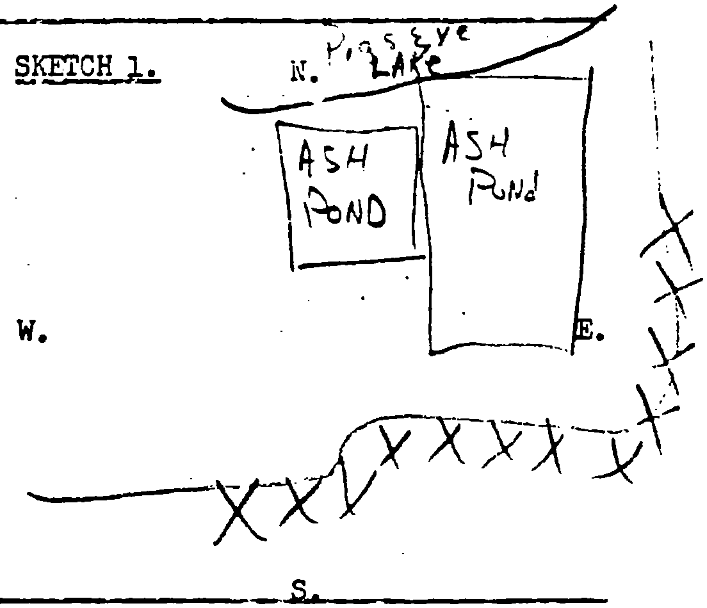
Complaintant: Rich Howard

Phone: 725 7976

Address: USCE

Recommendations: —Wait for pics
MWCC is going to have to start managing this stuff; I'll hit 'em w/ a nasty letter

SKETCH 1.



Action Taken:

MPCA 568

1010098

Don't need STM

week

Answer by Aug 22

01516

CONTECH

ready to spend money to do some test

Applications for Incinerator Sludge

need Guidelines for Incinerator ash as a admixture

conditional

need PCA position on incinerator

Cost tests

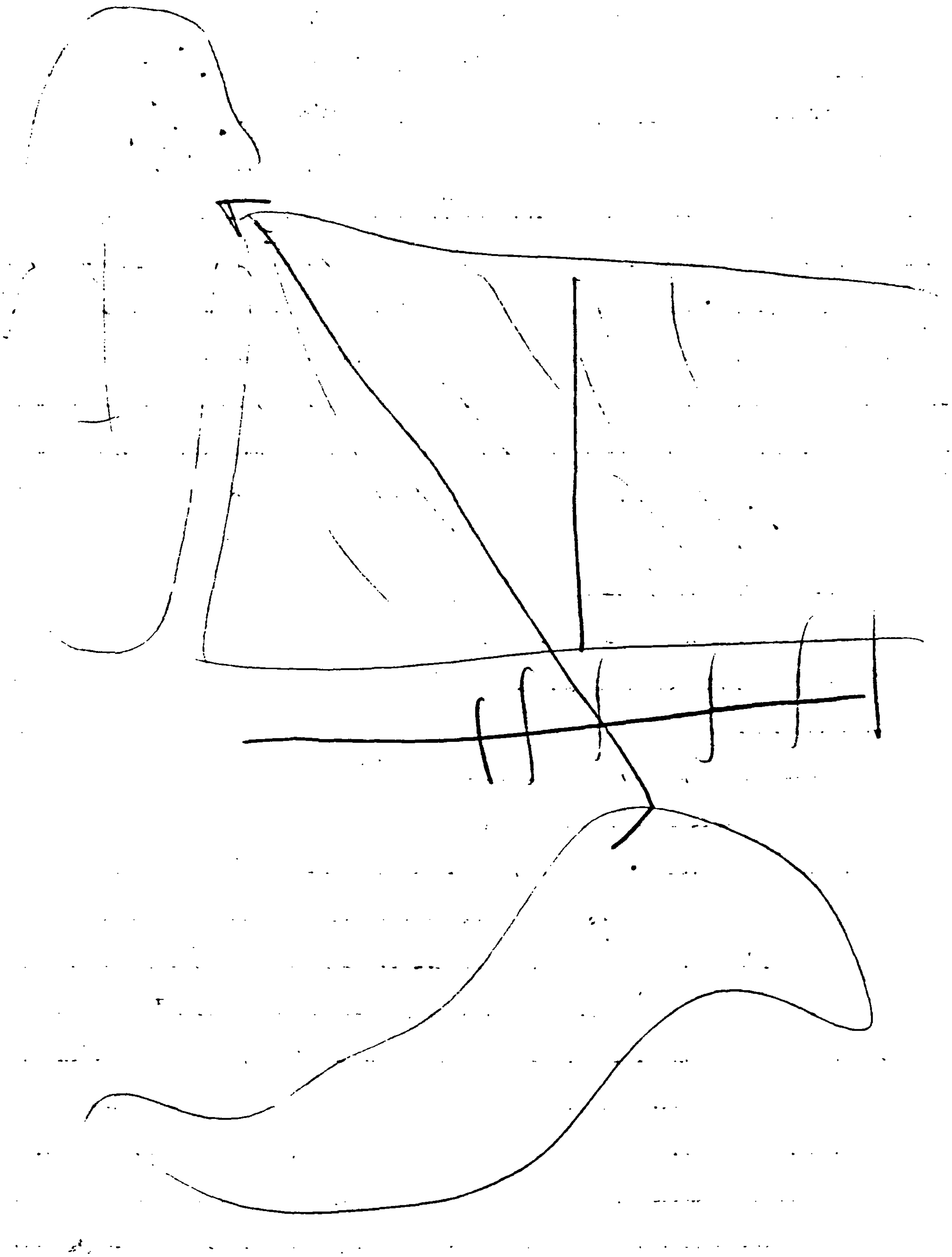
Attn Bob Dennis

CH2M Hill / CED

PO Box I.

Osseo MN 55369

1010096



September 1, 1978

Bernard J. Harrington
Director of Engineering
Metropolitan Waste Control Commission
350 Metro Square Building
Seventh and Robert Streets
St. Paul, MN 55101

CERTIFIED MAIL
(Return Receipt Requested)
(No. 290627)

RE: Disposal of Grit, Screenings, and other Wastes
Metropolitan Treatment Plant, Ramsey County, MN

Dear Mr. Harrington:

During a recent field investigation, several problems were noted in the area immediately west of the ash ponds in the SW¼ of Section 10, T.28N., R.22W.

As you may be aware, grit and screenings from the Metropolitan Plant are being transported and dumped at the above location and it appears that contaminated leachate is flowing from the material into the adjacent low lands west of the dumping site. Depending on the chemical nature of the material, pollution of surface and/or ground water may result from this type of disposal practice.

In addition to the grit and screenings noted at the site, two other types of wastes are being dumped at the same location. One of the wastes is whitish-grey in color while the other waste material is red in color.

Since a solid waste disposal facility permit has not been issued to the Metropolitan Waste Control Commission (MWCC) by the Minnesota Pollution Control Agency (MPCA) Board for disposal of these wastes, it would appear that the MWCC is in violation of Minnesota Regulation SW-5 which states in part that:

> "It shall be unlawful for any person to establish, maintain, conduct or operate an intermediate or final solid waste disposal site or facility except as provided in these regulations without first obtaining a permit from the Agency."

Naturally, any assessment of disposal alternatives for wastes of this nature must be based on sound chemical information about the wastes. Accordingly, you are hereby requested to arrange for the Metropolitan Waste Control Commission to perform a standardized leaching test (copy of procedure enclosed) on each of the waste types involved. Results of all tests performed must be submitted to this office within thirty (30) days of receipt of this letter.

In addition, it is requested that the MWCC prepare and submit a suitable solid waste disposal plan for these wastes within forty five (45) days of receipt of this letter. Said plan shall be based on the chemical results of leaching tests performed as well as on volumes and the physical nature of the wastes produced. Obviously, any such plan must also be consistent with all local, state, and federal rules and regulations.

Please contact this office if there are questions regarding these matters.

Sincerely,

DAC

Daniel A. Comeau
Soil Scientist
Enforcement Section
Division of Solid Waste

DAC:rrs

Enclosure (1)

cc: Richard Howard, Department of the Army, St. Paul District, Corps of Engineers, 1135 U.S. Post Office and Custom House, St. Paul, MN 55101
Ronald Harnack, Regional Hydrolotist, MN Dept. of Natural Resources, Division of Waters, 1200 Warner Road, St. Paul, MN 55106
Keith Baeeke, U.S. EPA, MN/WI District Office, 7401 Lyndale Avenue South, Minneapolis, MN 55423

bcc: Bruce W. Brott, Chief, Permits Section, Division of Solid Waste
Richard A. Svanda, Permits, Water Quality Division
Perry Beaton, Facilities, Water Quality Division
Tim K. Scherkenbach, Enforcement, Water Quality Division

01520

STICK POSTAGE STAMPS TO ARTICLE TO COVER POSTAGE (first class or airmail), **CERTIFIED MAIL FEE, AND CHARGES FOR ANY SELECTED OPTIONAL SERVICES.** (see front)

1. If you want this receipt postmarked, stick the gummed stub on the left portion of the address side of the article, **leaving the receipt attached**, and present the article at a post office service window or hand it to your rural carrier. (no extra charge)
2. If you do not want this receipt postmarked, stick the gummed stub on the left portion of the address side of the article, date, detach and retain the receipt, and mail the article.
3. If you want a return receipt, write the certified-mail number and your name and address on a return receipt card, Form 3811, and attach it to the back of the article by means of the gummed ends. Endorse front of article RETURN RECEIPT REQUESTED.
4. If you want delivery restricted to the addressee, or to an authorized agent of the addressee, endorse RESTRICTED DELIVERY on the front of the article. Check the appropriate blocks in Item 1 of the return receipt card.
5. Save this receipt and present it if you make inquiry.

1010102

UNITED STATES POSTAL SERVICE

OFFICIAL BUSINESS

1010103

PENALTY FOR PRIVATE USE TO AVOID PAYMENT OF POSTAGE, $300

SENDER INSTRUCTIONS

Print your name, address, and ZIP Code in the space below.
• Complete items 1, 2, and 3 on reverse side.
• Moisten gummed ends and attach to back of article.

RETURN TO

MINNESOTA POLLUTION CONTROL AGENCY
1935 West County Road B2
Solid Waste Division
Roseville, MN 55113

ATTN: Dan Comeau

01521

GPO: 1975-O-588-...

PS Form 3811, Jan. RETURN RECEIPT, REGISTERED, INSURED AND CERTIFIED MAIL

● SENDER: Complete items 1, 2, and 3. Add your address in the "RETURN TO" space on reverse.

1. The following service is requested (check one).
   - [x] Show to whom and date delivered .... 15¢
   - [ ] Show to whom, date, and address of delivery 35¢
   - [ ] RESTRICTED DELIVERY Show to whom and date delivered .... 65¢
   - [ ] RESTRICTED DELIVERY Show to whom, date, and address of delivery 85¢

RECEIVED ... 1978

2. ARTICLE ADDRESSED TO: MINN. POLLUTION CONTROL AGENCY
   Bernard Harrington
   MWCC
   350 Metro Square Bldg.
3. ARTICLE DESCRIPTION: St. Paul, MN

REGISTERED NO.	CERTIFIED NO.	INSURED NO.

(Always obtain signature of addressee or agent)

I have received the article described above.

SIGNATURE ☐ Addressee ☒ Authorized agent

4. DATE OF DELIVERY OCT 26 1978 — POSTMARK: OCT 27 1978 ST. PAUL, MN 551.. P. & COD ROOM
5. ADDRESS (Complete only if requested)
6. UNABLE TO DELIVER BECAUSE: — CLERK'S INITIALS

1010101

No. 290027

RECEIPT FOR CERTIFIED MAIL—30¢ (plus postage)

POSTMARK OR DATE

SENT TO Metropolitan Waste Control
Bernard J. Harrington

STREET AND NO.
350 Metro Square Building

P.O., STATE AND ZIP CODE
St. Paul, MN 55101

1010101

OPTIONAL SERVICES FOR ADDITIONAL FEES		
RETURN RECEIPT SERVICES	1. Shows to whom and date delivered	15¢
	With restricted delivery	65¢
	2. Shows to whom, date and where delivered	35¢
	With restricted delivery	85¢
RESTRICTED DELIVERY		50¢
SPECIAL DELIVERY (extra fee required)		

PS Form 3800 Aug. 1975 — NO INSURANCE COVERAGE PROVIDED— NOT FOR INTERNATIONAL MAIL — (See other side)

☆ GPO: 1975—O—591-452

01522

METROPOLITAN
WASTE
CONTROL
COMMISSION
Twin Cities Area

October 5, 1978

OCT 1 1 1978

MINN. POLLUTION
CONTROL AGENCY

Mr. Daniel A. Comeau
Soil Scientist, Enforcement Section
Division of Solid Waste
Minnesota Pollution Control Agency
1935 West County Road B2
Roseville, Minnesota 55113

Subject: Disposal of Solid Wastes
Metropolitan Wastewater Treatment Plant
Letter of September 1, 1978
MWCC Index No. 78-4007

Dear Mr. Comeau:

The purpose of this letter is to respond to your letter of September 1, 1978 to Mr. Harrington on the subject matter.

The Commission routinely disposes of only grit material removed in the plant grit facilities on the Metro Plant site. Screenings have for a number of years been hauled to a sanitary landfill for disposal.

The solid waste noted as red in color was in all probability floor sweepings and compound which were erroneously and inadvertently deposited on-site. Floor sweepings are normally included with solid waste which is hauled to a sanitary landfill.

The whitish-grey solid waste noted is grit material from cleaning the lime slakers. This material consists of either limestone which was not properly calcined to lime or other rock material which is an impurity in the limestone used for producing the pebble lime. The amount of this material generated is generally limited.

The Metropolitan Wastewater Treatment Plant has historically disposed of residual solids materials on site since the facility began operating in 1938. Only recently have past procedures changed: (1) incinerator ash, formerly sluiced for on site landfill disposal, has been deposited since August, 1975 in ash basins for subsequent removal and land disposal elsewhere; and (2) screenings, as previously noted, are now disposed of to a sanitary landfill, whereas in the past, they had been landfilled on site. Consequently, only grit materials are presently disposed of on-site.

350 METRO SQUARE BLDG.
7TH & ROBERT STREETS
SAINT PAUL MN 55101
612 222-8423

1010119

recycled

Your letter indicating that the disposal of grit on the Metro Plant site may be in violation of MPCA Regulation SW-5 is the first notification to our knowledge that these materials may require a permit at this time for the present method of disposal.

As the Agency is aware, the Commission is presently constructing over $150 million of solids processing facilities at the Metro Plant which completely change the solids processing procedures at the plant. Apparently the subject of applicable grit disposal methods and facilities was overlooked in considering these facilities. The new facilities do provide for dry handling and storage of incinerator ash for subsequent off-site landfill. The new solids processing facilities also change chemical conditioning of sludge from the lime-ferric chloride system presently used, to one relying entirely upon the use of polymers. Consequently, as the new solids processing facilities are placed on line in accordance with the schedule in the NPDES Permit issued June 1, 1978, the use of lime at the plant will be essentially eliminated; and the production of grit material from the lime slaking operation will be eliminated.

As the Agency is aware, the Commission has ongoing a 201 Facilities Planning Study which directly affects solid waste disposal considerations and methods at the Metro Plant: Residual Solids Management Study (RSMS), MWCC Project No. 75-01. The RSMS, initiated in May, 1977, has the objective to define and develop the most environmentally sound, cost-effective methods of processing and disposing of all residual solids generated at Commission facilities. The study, presently projected for total completion in October, 1979, will then determine the best alternative for grit disposal at the Metro Plant.

Based on historical grit disposal methods, the RSMS to determine the most feasible grit disposal alternative in coordination with other Commission residual solids disposal requirements, and the quality and quantity of grit as subsequently discussed, there appears to be no cogent reason at this time to accelerate any alternate disposal method implementation. Therefore, it is proposed that the solid waste plan for grit disposal consist of that which will be developed from the RSMS; and that the Agency provide its input to the study in terms of necessary data on grit required to define and analyze suitable alternative disposal methods. If the Agency determines that a solid waste disposal permit is required for the present method of disposal, then the Commission will apply for a permit when application requirements are defined.

Information on the present grit handling methods, quantities, and quality are the following:

1. Grit removal and handling facilities are essentially the same for the two pretreatment systems at the plant: grit is removed in grit chambers; the removed grit is pumped through hydrocyclones to dewater the grit; grit from the hydrocyclones drops into storage hoppers which enable further moisture removal by drainage; and grit from the hoppers is

loaded into trucks for transport to the on-site landfill area. The west pretreatment facilities remove grit in velocity control chambers. The new east pretreatment facilities remove grit in aerated grit chambers.

2. The quantity of grit from 1940 through 1968 shown in Table 1 and Figure 1 attached. The grit averaged about 5.2 cu.ft./mil. gal. and annual total solids content after drainage ranged from 80% to 90%.

3. The quantity of grit from 1976 through September, 1978, is shown in Table 2. In Table 3, data on the total solids content and volatile solids content of grit in 1978 are provided. The total solids data is somewhat different than previous years because of the new facilities placed into operation and the adjustments necessary to adapt to operation with the new facilities. Data from the summer period indicate that the total solids content should average about 80% or higher, with a volatile percentage of 10% to 20%.

4. Grit is transported by wastewater and, as a result, solubilizes any soluble substances into the wastewater over the period of time that grit is in contact with the wastewater. Consequently, raw wastewater characteristics, insofar that they represent totally soluble constituents, indicate the maximum leachate concentration possible and represent the concentration to be found in interstitial water of the drained grit. The raw wastewater characteristics of the Metro Plant influent are given in Table 4.

Based on the above information, the grit may be expected to have the following average characteristics:

Quantity	12,000 - 14,000 cu.yd./year
Total Solids, %	80% - 85%
% Volatile	10% - 15%
Wet Weight	80 - 85 lb./cu.ft.

As the grit is drained before disposal and contains only 15% to 20% moisture content, further drainage after disposal is expected to be minimal. Observations of possible drainage from grit piles may have been during operating problems with the drainage facilities on storage hoppers. Screens on the hoppers were binding and preventing removal of water through drainage piping. Modifications to the hoppers have been made to minimize or overcome this problem area.

BS

Based on the raw wastewater characteristics and low moisture content of the grit, there is no reason to believe that either drainage or leachate from landfilled grit present a problem.

In summary, there is no reason to believe that the present method of grit disposal at the Metro Plant represents any real problem that cannot await the results of the ongoing RSM study. Consequently, a detailed study of grit characteristics and disposal alternatives under this project will develop a suitable, cost-effective, and coordinated solid waste disposal plan. If a solid waste disposal permit is required for the present grit disposal program, then the Commission will file the required application as defined by the Agency.

If you have any questions, desire further information, or decide on further action necessary by the Commission, please inform us.

Sincerely,

Anthony C. Goerke
Deputy Chief Administrator

ACG/WAB/lb
10.6.78

cc: G. W. Lusher
B. J. Harrington
W. K. Johnson
D. C. Bergstedt
J. Corcoran
G. Wegwart, MPCA
V. K. Naidu

Attachments

TABLE NO. 1

ESTIMATED QUANTITIES OF GRIT REMOVED

Year	Flow Thru Plant	C.F. Per M.G.	C. F. Per Day	5 Yr. Average C.F./Day	Wet Wt. Per Cubic Ft.	Pounds Per Day Wet	Percent Solids	Pounds Per Day Dry
1940	104.2	6.2	645		86.9	56,000	84.9	47,500
1941	109.9	6.2	680		85.5	58,000	84.4	49,000
1942	115.1	5.4	736	612	87.8	64,500	87.7	56,500
1943	119.1	5.1	465	592	85.8	40,000	88.0	35,000
1944	122.2	5.0	538	590	83.6	45,000	85.0	38,000
1945	118.6	4.4	545	533	86.0	47,000	85.6	40,000
1946	119.3	4.4	668	536	86.7	58,000	83.1	48,000
1947	125.6	4.5	452	545	83.1	37,600	84.5	31,800
1948	122.8	4.5	478	549	75.1	36,000	82.2	29,600
1949	124.8	4.6	586	581	71.6	42,000	84.4	35,500
1950	122.3	4.8	562	615	74.2	41,700	83.0	34,700
1951	131.9	5.0	830	659	86.3	71,500	87.9	63,000
1952	135.2	5.2	621	700	85.5	53,200	87.7	46,600
1953	142.6	5.5	697	750	85.7	59,800	89.1	53,000
1954	138.6	5.7	790	790	79.6	63,000	85.4	54,000
1955	135.6	6.2	813	872	76.2	62,000	85.3	53,000
1956	139.2	6.2	1030	881	77.5	80,000	86.5	69,000
1957	149.0	6.2	1030	894	78.8	81,000	89.5	72,500
1958	143.5	6.1	745	900	76.0	56,500	82.7	46,500
1959	149.9	5.5	855	833	79.8	68,200	84.9	58,000
1960	158.2	5.3	840	798	82.4	69,200	86.8	60,100
1961	162.4	4.3	699	806	84.3	58,900	89.1	52,500
1962	178.1	4.8	851	797	87.9	74,800	88.3	66,000
1963	188.5	4.2	785	833	85.5	67,100	84.0	56,400
1964	188.0	4.3	811	883	92.4	74,900	86.6	64,900
1965	187.8	5.4	1019	906	95.3	97,100	87.9	85,400
1966	194.8	4.9	951	1021	87.9	83,600	85.6	71,600
1967	205.3	4.7	965		87.9	84,800	82.4	69,900
1968	215.0	6.3	1358		79.5	108,000	79.8	86,200
	Aver.	5.2			83.1			

TABLE 2

METROPOLITAN WASTEWATER TREATMENT PLANT

Quantities of Grit

1976 - 1978

Month Of Year	1976	1977	1978
	Quantities of Grit - 1000 Cu.Ft.		
January	7.8	7.3	24.5
February	11.9	23.5	14.0
March	21.3	26.3	19.8
April	20.8	24.7	26.8
May	16.6	25.7	24.6
June	22.9	34.4	34.6
July	23.2	44.5	38.7
August	23.0	35.0	30.9
September	17.4	46.8	24.2
October	16.3	42.3	
November	9.1	29.8	
December	10.0	17.7	
Total	200.3	358.0	*238.1
Cu.Ft./MG	2.82	5.03	*4.06

* for 9-month period January-September

TABLE 3

METROPOLITAN WASTEWATER TREATMENT PLANT

Grit Characteristics in 1978

Month Of Year	EAST PRETREATMENT No. of Values	EAST PRETREATMENT Total Solids Percent	EAST PRETREATMENT Total Solids % Volatile	WEST PRETREATMENT No. of Values	WEST PRETREATMENT Total Solids Percent	WEST PRETREATMENT Total Solids % Volatile
January	0	--		1	91.9	4.6
February	0	--		0		
March	1	22.8	82.3	0		
April	22	67.4	20.8	3	49.7	32.3
May	30	57.4	32.7	0		
June	36	68.5	20.6	0		
July	48	80.5	10.3	0		
August	38	77.9	14.2	1	86.1	6.8
September	9	64.4	20.9	0		

Notes:

1. East pretreatment facilities are new aerated grit chambers; placed into operation March 27, 1978; West pretreatment facilities are flow control grit chambers.
2. Samples are grab samples from trucks hauling grit
3. Samples which were not designated as either east or west were included in east values.
4. September values are through the 25th.

WAB/lb
10.5.78

TABLE 4

METROPOLITAN WASTEWATER TREATMENT PLANT

Raw Wastewater Characteristics

Characteristic	Annual Average in 1977
Flow, mgd	195
BOD, mg/l	246
COD, mg/l	631
TSS, mg/l	288
pH, S.V.	6.3-9.0
TKN, mg/l	24.4
Ammonia-N, mg/l	18.5
Total Phosphorus, mg P/l	6.1
Temperature, ^{o}C	17.9
Settleable Solids, ml/l	9.6
*Cadmium, mg/l	0.09
*Chromium (total), mg/l	0.61 → VI (6^+) ?
*Copper, mg/l	0.40
*Lead, mg/l	0.21
*Nickel, mg/l	0.20
*Zinc, mg/l	0.66

* Average influent concentration for March-October, 1977 during which period flow averaged 202 mgd

WAB/lb
10.5.78

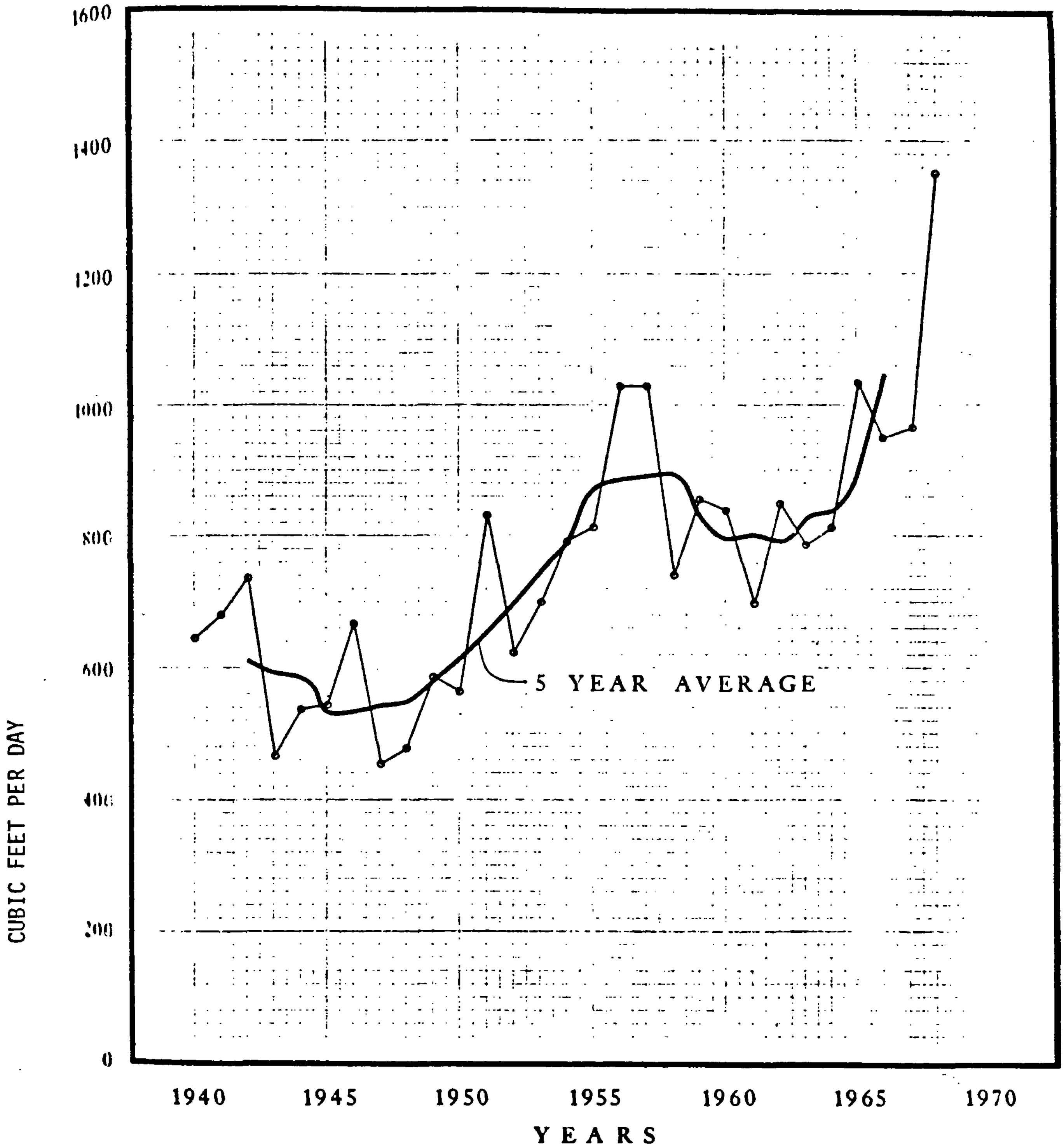


Figure 1

RECORDED QUANTITIES OF GRIT REMOVED

NEED: The ultimate disposal of solids is a major consideration in any waste disposal system. All plants in the Metropolitan Disposal System, with the exception of Metro and Seneca, produce digested sludge which is hauled to land disposal sites or to the Metro and Seneca plants for incineration. Incinerated sludge from Metro and Seneca is disposed in ash ponds and ultimately ends up in sanitary landfills. Grit and screenings from all plants is generally transported by commercial hauler and disposed in sanitary landfills. The hauling of sludge and waste solids is a major operational expense for the Metropolitan Disposal System. There is a need to coordinate the present disposal system into a systematic and efficient program. This includes inventorying the existing system, locating and developing regional disposal sites for sludge and solid waste material, investigating possible adaptations in the current sludge processing and transportation systems, and studying alternatives to the existing solids handling systems. There is also a need to develop interim solutions for small plants which are scheduled to be phased out within a few years. The following list of plants within the Metropolitan Disposal System are scheduled to be investigated under the 201 Facilities Planning Program, including the mode of sludge processing and ultimate solids disposal:

Anoka -- Produces 2,416,000 gallons of anaerobically digested sludge annually. Sludge formerly was spread on drying beds at a sanitary landfill site, but now is an interceptor and is eventually processed at Metro Wastewater Treatment Plant. Grit and screenings are disposed at a sanitary landfill (1974).

Apple Valley -- Produces 4,138,500 gallons of aerobically digested sludge annually. Sludge is disposed on land at Rosemount Experimental Station. Grit and screening are disposed at a sanitary landfill (1974).

Blue Lake -- 14,031,000 gallons of primary and aerobically digested waste activated sludge is hauled to Seneca or Metro annually. Grit and screening to sanitary landfill.

Bayport -- Produces 1,293,000 gallons of aerobically digested sludge which is hauled to Stillwater Wastewater Treatment Plant or Metro Wastewater Treatment Plant Disposal System. Grit and screening go to sanitary landfill.

Chaska -- 1,448,400 gallons of aerobically digested sludge is transported to Blue Lake Wastewater Treatment Plant Disposal System (and hence, to Seneca or Metro). Grit and screenings go to a sanitary landfill.

Cottage Grove -- 1,624,000 gallons of anaerobically digested sludge is dewatered on drying beds or hauled to Rosemount Experiment Station. Grit and screenings go to sanitary landfill.

Farmington -- 786,000 gallons of anaerobically digested sludge hauled to Rosemount experimental station annually. Grit and screenings go to a sanitary landfill.

Hastings -- 1,952,000 gallons of anaerobically digested sludge hauled to Rosemount experimental station annually. Grit and screenings are hauled to sanitary landfill.

Lakeville -- 311,500 gallons of anaerobically digested sludge go to Rosemount Experiment Station. 45,000 gallons went to drying beds with cake spread on farm owned by the operator in 1974. Grit and screenings are hauled to sanitary landfill.

1010110

Long Lake -- In 19 , 53,000 gallons of anaerobica digested 01532 transported to farm land and 8,500 gallons to drying beds where it was picked up by people for lawn and garden. In 1975, most sludge was hauled to an interceptor leading to Blue Lake or Metro. Grit and screenings are hauled to a sanitary landfill.

Maple Plain -- In 1974, 48,000 gallons of anaerobically digested sludge went to drying beds to be picked up by people for lawn and garden use. Grit and screenings are hauled to a sanitary landfill.

Metro -- Sludge is dewatered and incinerated, 43,898 gallons primary sludge plus 10% chemicals and 45,776 gallons mixed sludge plus 25% chemicals are disposed in ash ponds. Grit and screenings go to a sanitary landfill.

Orono -- In 1974, 700,000 gallons of aerobically digested sludge went to a local farm; 100,000 gallons went to a drying bed with cake picked up by people for lawn and garden use. Some sludge was hauled to interceptor feeding Blue Lake or Metro. Grit and screenings go to a sanitary landfill.

Prior Lake — In 1974, 21,000 gallons of anaerobically digested sludge hauled to Seneca for incineration; 148,000 gallons to sludge drying beds with cake disposal on site or to local farm land. Grit and screenings go to a sanitary landfill.

Rosemount -- Sludge hauled to Metro for incineration. Some sludge injected on-site in 1975 as part of research project.

Savage -- 280,000 gallons of anaerobically digested sludge is hauled to Seneca.

Seneca -- Sludge is incinerated and disposed in ash ponds. Ash eventually goes to a sanitary landfill. Screenings go to sanitary landfill. Grit is incinerated and disposed in ash ponds.

So. St. Paul — 240,000 gallons go to a sludge lagoon. Grit and screenings are hauled to a sanitary landfill.

Stillwater — 3,305,400 gallons of anaerobic digested sludge is hauled to local farm land or to the Metro Wastewater Treatment Plant Disposal System, and 120,000 gallons hauled to Rosemount Experimental Station in 1974. 35,400 gallons dewatered on drying beds and picked up by people for lawn and garden use. Grit and screenings go to a sanitary landfill.

The original Plan of Study for the 201 Facilities Plan contained two studies -- Ultimate Disposal of Solids and Utilization of Sludge from Small Plants -- that addressed the general problems of solids utilization and/or disposal. Because these two studies are so closely interrelated, it is proposed to combine them into one study, as hereinafter described.

Because the study is so extensive, the study will be divided into the following areas of study, listed in approximate sequenced order for initiation of the work: (1) Inventory of existing system; (2) Analysis of immediate needs; (3) Public information program; (4) Ultimate disposal site selection; (5) Fertilizer marketing study; (6) Interface with fertilizer marketability study; (7) Solids processing and transport; (8) Land managment plan; (9) Selection of total system plan and integration into Metropolitan Disposal System; and (10) Changing technolog and system flexibility. The studies are primarily directed toward land spreading

1010109

and/or sanitary landfill, considered at this time to be the two primary alternatives for ultimate disposal. The last section will address the fact that new solids processing and resource recovery technology is developing rapidly and that the final Solids Utilization/Disposal System selected must incorporate sufficient flexibility to accommodate this changing technology. Decisions made as part of the Ultimate Disposal Studies will provide the basic framework for addressing Ultimate Disposal as it relates to specific service area facilities plans.

SEP 0 4 1979

Mr. Bernard J. Harrington
Director of Engineering
Metropolitan Waste Control Commission
350 Metro Square Bldg.
St. Paul, MN 55101

RE: Inspection of Metropolitan Waste Control Commission Ash Disposal Site, SW-189

Dear Mr. Harrington:

This confirms the inspection conducted at the above referenced facility by Minnesota Pollution Control Agency Solid Waste Division staff on August 31, 1979.

During this inspection the following operational concerns were noted:

1. Prohibited wastes in the form of concrete, scrap wood, scrap metal, metal drums, household garbage and paper was observed in the unpermitted grit deposition area.

2. There are no fences or gates present which, in any way, control access to the site.

3. There is no site identification sign present.

4. To date, no fence has been constructed around the unpermitted grit deposition area, as was indicated by MWCC staff at a recent meeting.

5. At present, it was observed that grit is being deposited at the edge of the diked ash holding area and pushed in with a front-end loader. As such, it was confirmed that the unpermitted grit disposal area is no longer being utilized. It will still be required that some plan be submitted to deal with the matter of the grit which has already been deposited outside of the diked area.

Mr. Bernard J. Harrington
Page 2

This Agency is hopeful that these matters may be resolved shortly as a part of pending agreements between MWCC and Minnesota Pollution Control Agency.

Thank you.

Sincerely,

Jeff Harthun
Pollution Control Specialist
Enforcement Section
Division of Solid Waste

JH:ds
cc: Enrique Gentzsch, Ramsey County
: Dan Comeau, Enforcement Section, Solid Waste Division

JL
9/4

01536

Pollution Control Agency

SW189

Dan Comeau, Soil Scientist
Enforcement Section
Division of Solid Waste

Aug. 31, 1979

Jeff Harthun, P.C.S.
Envorcement Section
Division of Solid Waste

296-7288

INSPECTION OF MWCC ASH AND GRIT DISPOSAL SITE, SW-189

An inspection of this facility was conducted by me at 7:00 A.M. on August 31, 1979.

Currently grit is being deposited at the edge of the diked area and pushed into this ash lagoon with a front-end loader. This process has been observed during recent monthly inspections, since about June, 1979, as Mr. Bill Blaine stated at a recent meeting with MPCA staff held at 2:00 P.M. on August 24, 1979.

At this above referenced meeting, Mr. Blaine also indicated that a fence had been constructed around the unpermitted grit deposition area. However, no fence was observed at this inspection.

Other problems cited at this inspection were as follows:

1. Prohibited wastes were observed in the unpermitted grit deposition area. These wastes included demolition debris, household garbage, metal drums, and paper.

2. No site identification sign is present at the entrance.

3. There are notgates or fences present which would act to restrict access to the site.

JF/dar

1080034

MINNESOTA PO LUTION CONTROL AGENCY – SOLI WASTE DIVISI 01537

SOLID WASTE FACILITY SITE INSPECTION REPORT

SECTION I – GENERAL

ate 8-31-79 Facility Name MWCC Ash and Grit Disposal site MPCA Permit No. SW 189

County Ramsey Site Operator ______ Others Present ______

Type of Operation: Sanitary Landfill ______ Demolition Landfill ______ Modified Landfill ______ Other ash and Grit Dispos

Time 7:00 AM. Weather Conditions Partly Cloudy, 70°F Inspector Jeff Hartlun

Present Fill Area (Trench) according to Engineering Plans ______

Signature ______
Site Operator / Gate Attendant

SECTION II – OPERATING PROCEDURES – Violations of SW 6(2)

- ☐ (a) Open Burning
- ☐ (b) Leachate generation
- ☐ (c) Working Face – Litter Control
- ☐ (d)(i) Spreading and Compaction – Daily Cover
- ☐ (ii) Intermediate Cover Previously Filled Areas
- ☐ (iii) Cover Material Stockpile
- ☐ (iv) Cover Material Grading
- ☐ (e) Surface Water Drainage
- ☐ (f) Property Line Separation
- ☐ (g) Vermin Control
- ☐ (h) Approach and On-Site Access Roads
- ☐ (i) Dust Control
- ☐ (j) Equipment
- ☐ (k) Fire Protection Equipment
- ☐ (m) Sanitary Facilities and Shelter
- ☐ (n) Scavenging
- ☐ (o) Screening
- ☐ (p) Site Attendant
- ☒ (q) Gate and Fences
- ☒ (r) Sign
- ☐ (s) Water Monitoring System
- ☐ (t) Leachate Collection System
- ☐ (u) Gas Venting System
- ☒ (v) Prohibited Wastes
- ☐ (w) Hazardous Waste Storeage Area
- ☐ (y) Demolition Waste Area
- ☐ (z) Monthly Operational Reports Water Monitoring Reports
- ☐ (aa)(i) Final Cover of Terminated Areas
- ☐ (ii) Vegetation on Terminated Areas

Description of Violation (s)

Grit is currently being dumped at the edge of the diked area and pushed in with a front-end loader. This has been done for sometime, perhaps since about June, 1979, as Bill Blaine stated at recent meeting.

However, contrary to what Mr. Blaine said at this meeting, there is no fence around the unpermitted grit disposal area.

(q) no gate and fences controlling access.

(r) no sign identifying site

(v) Prohibited wastes observed at unpermitted grit disposal area

~~Violations of Special Permit Conditions~~ demolition debris, household garbage, paper, metal drums.

Pictures Taken ☒ Description 8 of grit disposal area and diked area

1080033

INSTRUCTIONS

Section I - General

Give date of inspection, name of facility, permit number, county in which facility is located, site operator's name, note others present, check type of operation, time of inspection, weather conditions at time of inspection and description of present fill area according to engineering plans.
Have site operator or gate attendant sign the report.

Section II - Operating Procedures

Place an "x" before each item determined to be in violation. Describe the nature of the violation.

(a) Open burning - Open burning is prohibited at sanitary landfills.
(b) Leachate generation - Is leachate being generated? Note location if there is a surface discharge. Also, note if samples were taken.
(c) Working face - Face should be as small as practicable.
Litter control - Appropriate barriers to prevent litter and daily collection of litter is required.
(d)(i) Spreading and compaction - Waste shall be uniformly distributed and compacted as densely as practicable.
Daily cover - Waste shall be covered with six inches of compacted soil daily.
(ii) Intermediate cover - Twelve inches of cover material applied to areas left for more than 120 days.
(iii) Cover material stockpile - Is there an adequate supply of cover material? Stockpile should be protected for winter operation.
(iv) Cover material grading - Cover material shall be graded to promote surface water runoff without excessive erosion.
(e) Surface water drainage - Surface water is diverted around and away from the landfill operating area.
(f) Property line separation - Twenty foot separation shall be maintained between the disposal operation and the adjacent property line.
(g) Vermin control - Effective means shall be used to control flies and rodents.
(h) Approach and on-site access roads - These roads shall be maintained in good condition.
(i) Dust control - Adequate dust control on-site shall be provided.
(j) Equipment - Equipment suitable to operate the site shall be available at all times.
(k) Fire protection equipment - Equipment to control accidental fires shall be kept at the site.
(m) Sanitary facilities and shelter - Maintenance buildings and sanitary facilities shall be available.
(n) Scavenging - Scavenging is prohibited.
(o) Screening - Screening shall be provided as per the site engineering plans.
(p) Site attendant - Site attendant shall be on duty at all times when the site is open for operation.
(q) Gate and fences - Gate and fencing shall be provided as per site engineering plans.
(r) Sign - Permanent sign at entrance with proper information.
(s) Water monitoring system - Monitoring system installed as per site engineering plans.
(t) Leachate collection system - Leachate collection system installed and operated as per site engineering plans.
(u) Gas venting system - Gas venting system installed and operated as per site engineering plans.
(v) Prohibited wastes - Those wastes as identified in Agency Regulation SW 6(2)(v) are prohibited for deposit in sanitary landfills.
(w) Hazardous waste storage area - A hazardous waste storage area shall be provided. A sign should properly identify this area.
(y) Demolition waste area - If provided, the demolition waste area shall be maintained in an acceptable manner.
(z) Monthly operational reports - Operational reports shall be submitted to the Agency monthly.
Water monitoring reports - Water monitoring reports shall be submitted to the Agency on a quarterly basis or as specified.
(aa)(i Final cover of terminated areas - Two feet of cover applied to completed areas within one month. Final cover graded to minimum 2% slope.
(ii) Vegetation on terminated areas - Suitable vegetation shall be maintained on terminated areas.

Violation(s) of special permit conditions - List and describe violation(s) of special conditions of the site permit.

Note whether pictures were taken and describe what picture represents.

Forward the original report to the Section Chief, Section of Enforcement, Solid Waste Division, 1935 West County Road B2, Roseville MN 55113, one copy to the MPCA regional office, one copy to the facility permittee and one to the county solid waste officer.

01539

OCT 24 1979

Mr. Bernard J. Harrington
Director of Engineering
Metropolitan Waste Control Commission
350 Metro Square Bldg.
St. Paul, MN 55101

RE: Inspection of Metropolitan Waste Control Commission Ash Disposal Site, SW-189

Dear Mr. Harrington:

This indicates that an inspection of the above referenced facility was conducted by Minnesota Pollution Control Agency and Ramsey County officials on October 16, 1979.

Certain operational concerns were observed during this inspection:

1. Prohibited wastes in the form of household garbage, demolition debris, cans and bottles were noted.

2. There are still no gates or fences present which would act to restrict access.

3. No site identification sign is present.

4. It was currently observed that considerable amounts of earthen cover material have been stockpiled on the surface of the unpermitted grit disposal area. It was requested in the last monthly inspection letter that some plan be submitted to deal with grit which has already been deposited as well as grit which is presently being pushed into the diked area. Simply covering this grit disposal area would probably not be acceptable, if this is what is proposed, especially since a wide variety of other solid wastes have been buried here in recent months. Please respond to this Agency indicating what MWCC plans are for this grit disposal area.

3. A final problem observed at this inspection is the basic problem of the decreasing amount of space available in the ash disposal diked areas.

The Minnesota Pollution Control Agency Solid Waste Division is still hopeful that the above matters may be resolved shortly.

Sincerely,

Jeff Harthun
Pollution Control Specialist
Enforcement Section
Division of Solid Waste

JH:ds
cc: Enrique Gentzsch, Ramsey County

JL
10/24

01541

MINNESOTA POLLUTION CONTROL AGENCY – SOLID WASTE DIVISION

SOLID WASTE FACILITY SITE INSPECTION REPORT

SECTION I – GENERAL

Date 10-16-79 Facility Name MWCC Ash Disposal site MPCA Permit No. SW 189

County Ramsey Site Operator ______ Others Present ______

Type of Operation: Sanitary Landfill ______ Demolition Landfill ______ Modified Landfill ______ Other ash and grit disposal site

Time 2:00 P.M. Weather Conditions Clear, 65°F Inspector Jeff Hertzhun, Enrique Gentzsch

Present Fill Area (Trench) according to Engineering Plans ______

Signature ______
Site Operator / Gate Attendant

SECTION II – OPERATING PROCEDURES – Violations of SW 6(2)

- ☐ (a) Open Burning
- ☐ (b) Leachate generation
- ☐ (c) Working Face – Litter Control
- ☐ (d)(i) Spreading and Compaction – Daily Cover
- ☐ (ii) Intermediate Cover Previously Filled Areas
- ☐ (iii) Cover Material Stockpile
- ☐ (iv) Cover Material Grading
- ☐ (e) Surface Water Drainage
- ☐ (f) Property Line Separation
- ☐ (g) Vermin Control
- ☐ (h) Approach and On-Site Access Roads
- ☐ (i) Dust Control
- ☐ (j) Equipment
- ☐ (k) Fire Protection Equipment
- ☐ (m) Sanitary Facilities and Shelter
- ☐ (n) Scavenging
- ☐ (o) Screening
- ☐ (p) Site Attendant
- ☒ (q) Gate and Fences
- ☒ (r) Sign
- ☐ (s) Water Monitoring System
- ☐ (t) Leachate Collection System
- ☐ (u) Gas Venting System
- ☒ (v) Prohibited Wastes
- ☐ (w) Hazardous Waste Storeage Area
- ☐ (y) Demolition Waste Area
- ☐ (z) Monthly Operational Reports Water Monitoring Reports
- ☐ (aa)(i) Final Cover of Terminated Areas
- ☐ (ii) Vegetation on Terminated Areas

Description of Violation (s)

A considerable amount of clean fill, with some demo. mixed in is being hauled in, apparently as ~~[illegible]~~ cover for the grit disposal area.
(V) Prohibited wastes noted in the form of household garbage, demo. debris, some cans and bottles.
(q) no gates or fences present to control access.
(r) no site identification sign present.

Violations of Special Permit Conditions ______

Pictures Taken ☒ Description 2 of grit disposal area, 2 of cover material being hauled in.

1080038

INSTRUCTIONS

Section I - General

Give date of inspection, name of facility, permit number, county in which facility is located, site operator's name, note others present, check type of operation, time of inspection, weather conditions at time of inspection and description of present fill area according to engineering plans.
Have site operator or gate attendant sign the report.

Section II - Operating Procedures

Place an "x" before each item determined to be in violation. Describe the nature of the violation.

(a) Open burning - Open burning is prohibited at sanitary landfills.
(b) Leachate generation - Is leachate being generated? Note location if there is a surface discharge. Also, note if samples were taken.
(c) Working face - Face should be as small as practicable.
Litter control - Appropriate barriers to prevent litter and daily collection of litter is required.
(d)(i) Spreading and compaction - Waste shall be uniformly distributed and compacted as densely as practicable.
Daily cover - Waste shall be covered with six inches of compacted soil daily.
(ii) Intermediate cover - Twelve inches of cover material applied to areas left for more than 120 days.
(iii) Cover material stockpile - Is there an adequate supply of cover material? Stockpile should be protected for winter operation.
(iv) Cover material grading - Cover material shall be graded to promote surface water runoff without excessive erosion.
(e) Surface water drainage - Surface water is diverted around and away from the landfill operating area.
(f) Property line separation - Twenty foot separation shall be maintained between the disposal operation and the adjacent property line.
(g) Vermin control - Effective means shall be used to control flies and rodents.
(h) Approach and on-site access roads - These roads shall be maintained in good condition.
(i) Dust control - Adequate dust control on-site shall be provided.
(j) Equipment - Equipment suitable to operate the site shall be available at all times.
(k) Fire protection equipment - Equipment to control accidental fires shall be kept at the site.
(m) Sanitary facilities and shelter - Maintenance buildings and sanitary facilities shall be available.
(n) Scavenging - Scavenging is prohibited.
(o) Screening - Screening shall be provided as per the site engineering plans.
(p) Site attendant - Site attendant shall be on duty at all times when the site is open for operation.
(q) Gate and fences - Gate and fencing shall be provided as per site engineering plans.
(r) Sign - Permanent sign at entrance with proper information.
(s) Water monitoring system - Monitoring system installed as per site engineering plans.
(t) Leachate collection system - Leachate collection system installed and operated as per site engineering plans.
(u) Gas venting system - Gas venting system installed and operated as per site engineering plans.
(v) Prohibited wastes - Those wastes as identified in Agency Regulation SW 6(2)(v) are prohibited for deposit in sanitary landfills.
(w) Hazardous waste storage area - A hazardous waste storage area shall be provided. A sign should properly identify this area.
(y) Demolition waste area - If provided, the demolition waste area shall be maintained in an acceptable manner.
(z) Monthly operational reports - Operational reports shall be submitted to the Agency monthly.
Water monitoring reports - Water monitoring reports shall be submitted to the Agency on a quarterly basis or as specified.
(aa)(i) Final cover of terminated areas - Two feet of cover applied to completed areas within one month. Final cover graded to minimum 2% slope.
(ii) Vegetation on terminated areas - Suitable vegetation shall be maintained on terminated areas.

Violation(s) of special permit conditions - List and describe violation(s) of special conditions of the site permit.

Note whether pictures were taken and describe what picture represents.

Forward the original report to the Section Chief, Section of Enforcement, Solid Waste Division, 1935 West County Road B2, Roseville MN 55113, one copy to the MPCA regional office, one copy to the facility permittee and one to the county solid waste officer.

1080037

Business Item "G"/ Beott

01543

METROPOLITAN WASTE CONTROL COMMISSION

350 Metro Square Building, Saint Paul, Minnesota 55101
222-8423

From G.E. Wegwart
JMM

MEMORANDUM

August 31, 1979

SUBJECT: APPROVAL OF PLANS AND SPECIFICATIONS AND AUTHORIZATION TO ADVERTISE FOR BIDS, METROPOLITAN WWTP ASH DISPOSAL PROJECT

The Metropolitan Wastewater Treatment Plant produces approximately 75,000 cubic yards of ash each year as a by-product of sludge incineration. The ash is sluiced to three settling basins for temporary storage. It is anticipated the basins will be completely full within 7-8 months. Previously we disposed of the ash at the old St. Paul Landfill which is adjacent to the Metropolitan WWTP. The land is owned by the St. Paul Port Authority and the Milwaukee Railroad. The two parties have allowed utilization of the old landfill because large sections had inadequate amounts of cover material.

How much is proposed? EAW? Dew

There is sufficient land at the old landfill to deposit an additional 100,000 yards of ash. The ash will be utilized as a final cover over the landfill. The area will be graded and sloped, to channel runoff away from the landfill. This diminishes leachate potential from both the ash and existing refuse. The area will also be covered with top soil and seeded.

Plans and Specifications have been prepared by the staff. The project cost is estimated to be $400,000.

RECOMMENDATION

It is recommended that the Commission approve the Plans and Specifications for the Metropolitan WWTP Ash Disposal project and authorize the Chairman and Chief Administrator to advertise for bids contingent upon approvals from the Metropolitan Council and the Minnesota Pollution Control Agency.

FUNDING AUTHORIZATION

1979 Program Budget, Program 039, Amount Provided $13,926,767, Amount Unencumbered $7,670,461, Amount of This Request $400,000.

Reviewed by:

Anthony C. Gnerre
Deputy Chief Administrator

Prepared by:

Bernard J. Harrington
Director of Engineering

BJH:WGM:nc

Bu'iness Item "G"

01544

M E T R O P O L I T A N   W A S T E   C O N T R O L   C O M M I S S I O N
350 Metro Square Building, Saint Paul, Minnesota 55101
222-8423

RESOLUTION NO. 79-270

APPROVAL OF PLANS AND SPECIFICATIONS AND AUTHORIZATION TO ADVERTISE FOR BIDS, METROPOLITAN WWTP ASH DISPOSAL PROJECT

BE IT RESOLVED, That the Metropolitan Waste Control Commission hereby approves the plans and specifications for the Metropolitan WWTP Ash Disposal Project and authorizes the Chairman and Chief Administrator to advertise for bids. Funds are provided in the 1979 Budget, Program 039, in the Amount of $400,000.

Adopted this 18th day of September, 1979

M E T R O P O L I T A N   W A S T E   C O N T R O L   C O M M I S S I O N

By ______________________________
Salisbury Adams, Chairman

By ______________________________
Richard J. Dougherty, Chief Administrator

RJD:WGM:nc

1010178

METROPOLITAN COUNCIL
Suite 300 Metro Square Building, Saint Paul, Minnesota 55101

March 3, 1980

MEMORANDUM

TO: Solid and Hazardous Waste Management Advisory Committee

FROM: Environmental Planning Division Staff
(Paul Smith and Carl Schenk)

SUBJECT: Proposed Disposal of Ash from the Metropolitan Wastewater Treatment Plant near Pig's Eye Lake, St. Paul
Metropolitan Council District No. 3
Metropolitan Council Referral File Number 8093-1 and File Number 8093-2

I. INTRODUCTION

The referenced project was submitted to the Council by the Minnesota Pollution Control Agency and Environmental Quality Board for review under the requirements of Minnesota statutes which require Council approval of solid waste disposal facilities before the Minnesota Pollution Control Agency (MPCA) can issue a permit for such a facility and under the Mississippi River Critical Area designation and Interim Development Regulations respectively.

Two types of action are required of the Physical Development Committee: 1. the approval or denial of the application for a solid waste permit for this project and 2. a finding of consistency with Mississippi River Corridor Critical Area Interim Development Regulations and a recommendation to the EQB on the appropriateness of this project.

II. AUTHORITY FOR REVIEW

Under state law (Minnesota Statutes 473.823, Subdivision 3) the Metropolitan Council must review and approve solid waste disposal facilities for consistency with the Solid Waste Management Chapter of the Metropolitan Development Guide before the Pollution Control Agency can issue a permit for such a facility.

The Governor's Executive Order Number 79-19 designating the Mississippi River Corridor as a state Critical Area requires that the Council review certain proposed developments and make a recommendation to the Environmental Quality Board. The

Executive Order and Council procedures allow the Council to hold a public hearing on proposed developments referred to it for Critical Area review. The Metropolitan Council is then to forward its final recommendations to the Environmental Quality Board within 30 days of the closing of the public hearing.

The proposed Pig's Eye Ash Disposal Project is subject to Critical Area review because it is a governmental development, since it is being proposed by the Metropolitan Waste Control Commission (MWCC) and it involves the alteration of the floodplain.

III. PROPOSED PROJECT DESCRIPTION

The Metropolitan Waste Control Commission proposes to empty two (Basins 1 and 2) of the three ash lagoons at the Metropolitan (Pig's Eye) Wastewater Treatment Plant and dispose of the ashes on the former St. Paul landfill site. The ash is a product of the sludge incineration process at the treatment plant. (The Metro Plant currently produces about 75,000 cubic yards of ash per year.) The ash materials are sluiced from the plant into the lagoons where the solids settle out of suspension and the liquids are discharged into Pig's Eye Lake. (Figure 1) Two of the three lagoons havebeen filled. In order for the system to function properly and to prevent violations of the state NPDES permit these lagoons must be emptied.
Approximately 100,000 cubic yards of ash material at an estimated cost of $300,000 will be removed from two of the basins and spread on a sixteen acre area on the former city landfill site to a depth of one to four feet depending on the site conditions. In addition six inches of soil will be provided to cover the ashes, and the area will be seeded. Daily cover will be required if ash is deposited at the site under non-freezing conditions. Daily cover will consist of six inches of soil. The area will be sloped to facilitate runoff towards Pig's Eye Lake to the south. Battle Creek flows along the west side of the site.

The proposed disposal area covers or includes a portion of a similar ash disposal site approved by the Metropolitan Council and MPCA in late 1977. During December, 1977 and January, 1978 two basins were emptied and approximately 136,000 cubic yards of ash were spread over 31 acres of the former landfill. Six inches of topsoil were applied and the area seeded. See Figures 1 and 2.

The land is presently owned by the St. Paul Port Authority but it will be transferred to the city shortly for development as part of Pig's Eye Regional Park. The Metropolitan Waste Control Commission has applied to the City of St. Paul for a conditional use permit for this project. The City Planning Commission will hold a hearing on this matter on March 6.

IV Project Review

There are several potential issues regarding the consistency of

01547

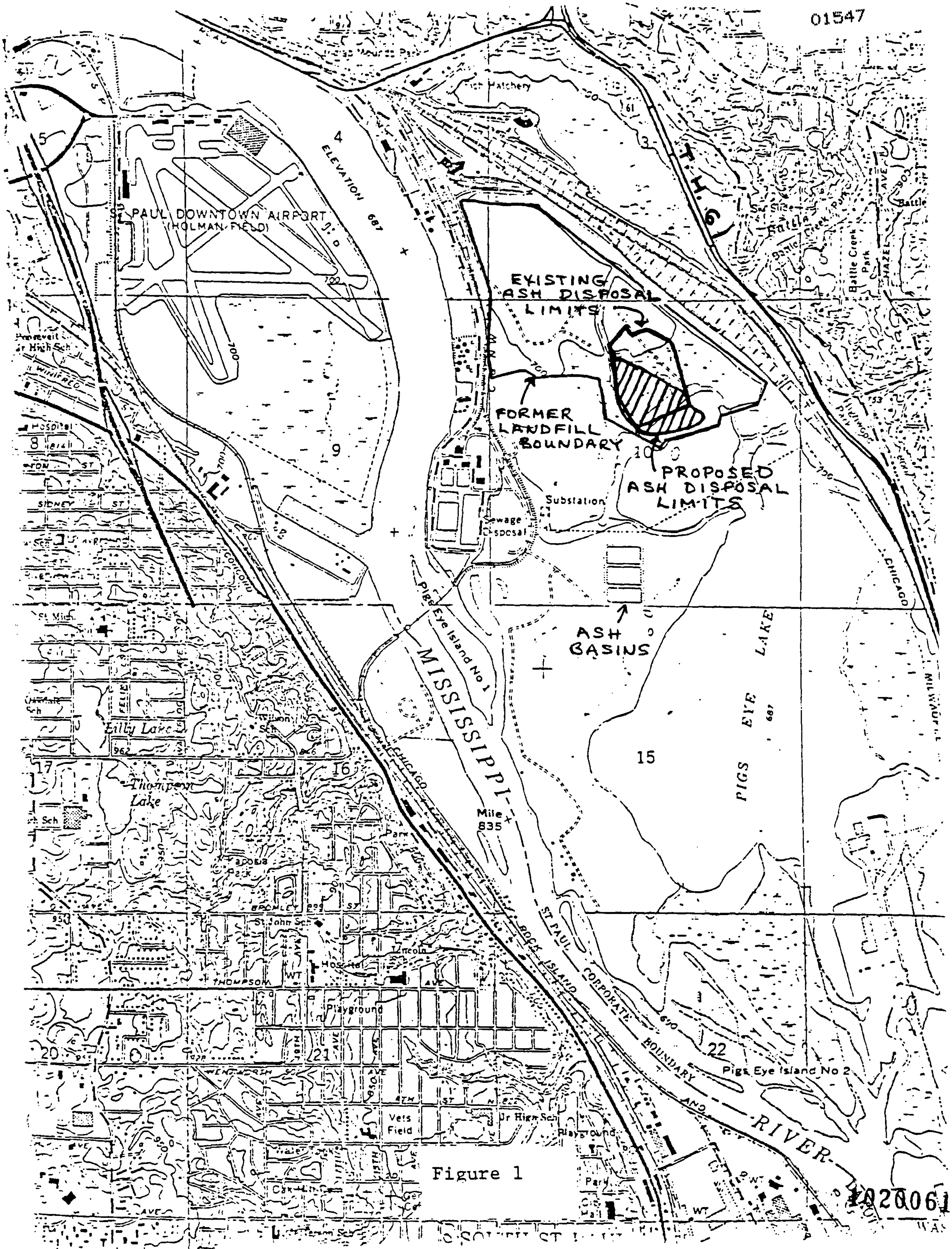
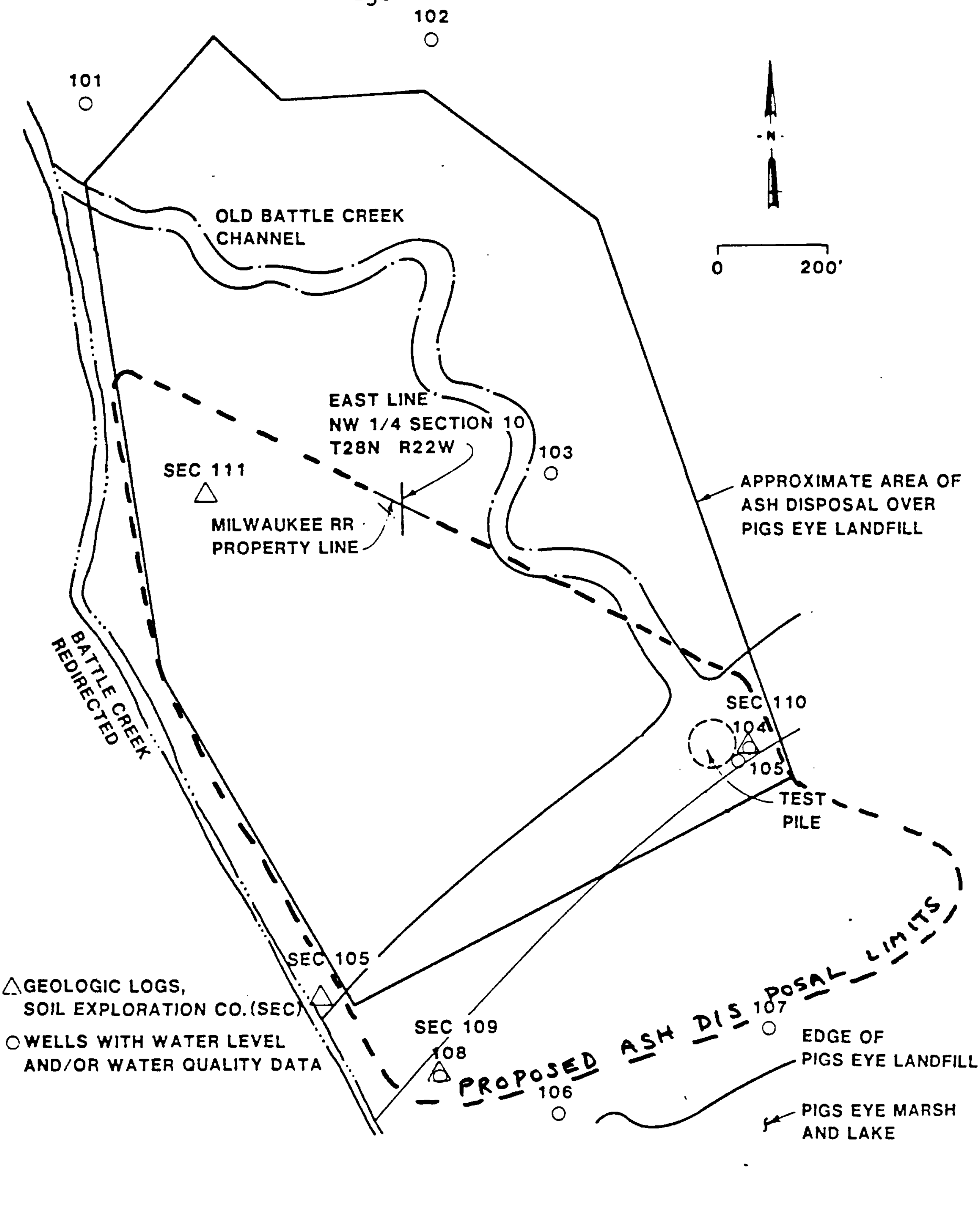


Figure 1

1020061



1020060

LOCATION OF WELLS AND PHYSICAL FEATURES OF ASH DISPOSAL SITE
EXISTING & PROPOSED

Figure 2

the proposed development with the Solid Waste Management Chapter of the Metropolitan Development Guide and the Mississippi River Critical Area designation. These issues are as follows:

- o The first issue relates to the consistency of the proposed development with the Solid Waste Management Chapter.
- o The Metropolitan Council and EQB recently reviewed St. Paul's Critical Area plan and regulations for the entire river corridor including the Pig's Eye Lake area. The second issue to be addressed is the consistency of this project with the City's plan for the end use of the Pig's Eye Lake area.
- o The proposed development is located in the floodplain near Battle Creek and Pig's Eye Lake. The third issue concerns the potential for degradation of surface and groundwaters in the area.
- o The Metropolitan Council in its review and approval of the previous ash disposal development on the former city landfill area recommended that the MWCC analyze alternative uses and methods for disposing of ash materials for the period to 1981. The third issue concerns the availability of alternatives to the proposed development and their environmental and economic implications.

A. Consistency With Solid Waste Guide Chapter

There are several issues regarding the consistency of the proposed project with the Solid Waste Management chapter of the Metropolitan Development Guide. These issues are as follows:

- o The facility's location is based on information which establishes that the waste and its constituents may be assimilated by the disposal environment without degrading the quality of the off-site environment.
- o A sound environmental monitoring program is conducted at the site.
- o The determination that other waste management practices and locations are not feasible.
- o Compatibility of the proposed project with county and municipal solid waste and land use plans.

1. The proposed ash disposal site is located on the abandoned St. Paul (Pig's Eye) Landfill north of the Pig's Eye Lake and adjacent to the Metro Waste Treatment Plant. This landfill was operated by the City of St. Paul from about 1956 to 1971. Residential, commercial, and industrial refuse was deposited in the landfill. Industrial chemicals in liquid and containerized drums were also put in the landfill. In November 1977, a solid waste permit was issued by the MPCA allowing the MWCC to spread

sludge incinerator ash over a portion of the abandoned landfill. The proposed project is a horizontal extension of the area covered under the 1977 permit. (See Figure 2.)

The proposed ash disposal site is located on an alluvial bar on the east side of the Mississippi River flood plain. The alluvial bar has been submerged several times in the past and the area has alternated between alluvial bar and marsh at least four times. The landfill area is completely surrounded by bodies of surface water and ground water levels are directly influenced by changes in the stage of these adjacent bodies. Since the Mississippi River flows south, the overall movement of ground water beneath the site is also to the south. On a smaller scale, however, the orientation and permeability of the underlying sediments causes considerable variance from this general southward flow.

The chemical characteristics of the sludge incinerator ash that was previously deposited on the landfill site are shown in Table 1. The ash has a high pH due to conditioning of the wastewater sludge prior to dewatering and subsequent incineration. This also increases the calcium and iron concentrations in the ash.

A leachate test was run by the MWCC on the ash in the ponds on June 8, 1977 prior to the previous ash disposal. The results of this test are presented in Table 2 along with Minnesota Department of Health (MnDOH) drinking water standards. MPCA reviewed the test results and stated that the metals in the ash were relatively insoluble and should not migrate from the deposited ash.

Data on the average ground water quality under the abandoned landfill prior to the previous ash disposal is presented in Table 3. Comparison of this quality with the MnDOH and U.S. EPA drinking water standards, also contained in Table 3, shows that the ground water did not meet drinking water standards. The ground water quality was very close to the limitations for most of the metals, such as cadmium , chromium, and lead. Values for iron and ammonia exceeded the standards or recommendations. In addition, the ground water contained a high concentration of organic compounds, as evidenced by the large chemical oxygen demand.

A summary of the apparent changes in ground water quality after the previous disposal of ash at the site are shown in Table 4. As shown in Table 4, there was no apparent change in the concentrations of cadmium, total chromium, and chromium (VI) in the water from wells 101, 102, 104 and 106 (see figure 2 for location of wells). The concentration of copper in the water from these wells did not appear to change, except in well 101. The copper concentration rose slightly, but was still below the drinking water standard of 1.0 mg/l.

The mercury concentration varied in the water from the four wells, but was generally below the recommended drinking water standard of 2.0 parts per billion. Water from well 101, which

Table 1
CHEMICAL CHARACTERISTICS OF METRO PLANT SLUDGE INCINERATOR ASH

Parameter	Concentration October 1977 [a] (mg/ kg)	November 1977 [b] (mg/ kg)
Ag	—	77
Al	—	29,700
Ba	—	166
Ca	—	242,000
Cd	47	50
Co	—	20
Total Cr	2,824	1,180
Cu	2,170	1,820
Fe	—	15,100
Hg	0.11	Negligible
Mg	—	12,600
Mn	—	233
Ni	533	96
Pb	571	60
Zn	2,548	1,070
pH	—	10.75

a Grab sample of ash collected and analyzed by the MWCC.

b Grab sample from ash lagoon collected and analyzed by CH_2M HILL.

Table 2
ASH LEACHATE TEST RESULTS

Parameter	Water Elutant First 200 ml (mg/ l)	Water Elutant Last 200 ml (mg/ l)	Acid Elutant First 200 ml (mg/ l)	Acid Elutant Last 200 ml (mg/ l)	MnDOH Drinking Water Standards[a] (mg/l)
Cd	0.01	0.01	0.05	0.10	0.01
Total Cr	6.30	1.05	3.90	4.05	—[b]
Cu	0.85	0.05	0.71	2.20	1
Hg	0.6[c]	0.2[c]	0.8[c]	0.2[c]	—
Ni	0.09	0.05	0.34	0.91	–
Pb	0.06	0.05	0.54	1.16	0.05
Zn	0.03	0.02	0.06	2.82	5
pH	9.45	10.85	—	—	6.5-8.5[d]

a Class A Standards.
b Standard for Cr (VI) is 0.05 mg/l.
c Concentration in ppb.
d Standard for Surface Water Quality.

Source: MWCC; average of results from tests on 6/3, 6/16, and 6/29/77.

Table 3
AVERAGE GROUNDWATER CHARACTERISTICS PRIOR TO ASH DISPOSAL

Parameter	Value (mg/ l)	MnDOH Drinking Water Standards[b] (mg/l)
Cd	0.02	0.01
Cn	0.009	0.01
Cr	0.05	—
Cu	0.02	1.0
Fe	0.33	0.3
Hg[a]	0.5	—
Mn	0.67	0.05
Ni	0.07	—
Pb	0.05	0.05
Zn	0.13	5
pH	7.7	6.5 - 8.5
COD	267	—
BOD	16	—
ALKALINITY	1338	—
TKN	135	—
NH_3–N	132	—
NO_3–N	0.75	10

a Concentration in ppb.

b Class A Standards.

Source: MWCC; average results from sampling on 6/16/77 and 6/28/77 at wells 104 through 108.

TABLE 4
APPARENT GROUND WATER QUALITY CHANGES FOLLOWING ASH DISPOSAL

PARAMETER	WELL 101	WELL 102	WELL 104	WELL 106
Cd	NO APPARENT CHANGE	NO APPARENT CHANGE	NO APPARENT CHANGE	NO APPARENT CHANGE
TOTAL Cr	NO APPARENT CHANGE	NO APPARENT CHANGE	NO APPARENT CHANGE	NO APPARENT CHANGE
Cr (VI)	NO APPARENT CHANGE	NO APPARENT CHANGE	NO APPARENT CHANGE	NO APPARENT CHANGE
Cu	VARIES SLIGHTLY, BUT BELOW DRINKING WATER STANDARD (1.0 mg/l)[a]	NO APPARENT CHANGE	NO APPARENT CHANGE	NO APPARENT CHANGE
Hg	VARIABLE INCREASE AND DECREASE, BUT BELOW RECOMMENDED DRINKING WATER STANDARD (2.0 mg/l)[b]	INCREASES FOR TWO SAMPLES, BUT THEN DECREASES BELOW RECOMMENDED DRINKING WATER STANDARD (2.0 mg/l)[b]	VARIABLE, BUT GENERALLY BELOW RECOMMENDED DRINKING WATER STANDARD (2.0 mg/l)[b]	VARIABLE, BUT BELOW RECOMMENDED DRINKING WATER STANDARD (2.0 mg/l)[b]
Ni	SLIGHT INCREASE AND THEN DECREASES; NO DRINKING WATER STANDARD	NO APPARENT CHANGE	NO APPARENT CHANGE	NO APPARENT CHANGE
Pb	AT DRINKING WATER STANDARD INITIALLY (0.05 mg/l);[a] INCREASES, BUT THEN DECREASES	SLIGHT VARIABILITY	AT DRINKING WATER STANDARD INITIALLY (0.05 mg/l)[a] AND VARIES PERIODICALLY ABOVE THIS LEVEL	AT DRINKING WATER STANDARD INITIALLY (0.05 mg/l)[a] AND VARIES PERIODICALLY ABOVE THIS LEVEL
Zn	INCREASES, BUT LEVELS OFF BELOW DRINKING WATER STANDARD (5 mg/l)[a]	VARIABLE, BUT INCREASES SLIGHTLY TO A LEVEL BELOW 0.2 mg/l	INCREASES TO A LEVEL OF ABOUT 0.5 mg/l, WHICH IS BELOW DRINKING WATER STANDARD (5 mg/l)[a]	INCREASES TO A LEVEL OF ABOUT 7 mg/l
ALKALINITY	INCREASES, BUT THEN STARTS TO DECREASE	INCREASES, BUT THEN STARTS TO DECREASE	INCREASES, BUT THEN STARTS TO DECREASE	INCREASES TO A CONSTANT LEVEL
pH	VARIABLE, BUT DECREASES FROM ABOUT 8.0 TO 6.5	DECREASE FROM ABOUT 8.0 TO 6.9	DECREASE FROM ABOUT 7.7 TO 6.7	DECREASE FROM ABOUT 7.7 TO 6.7

[a] MnDOH Class A Drinking Water Standards.

[b] Water Quality Standards for Drinking Water (Ref. 13).

is up-gradient of the ash disposal site, showed the only apparent change in nickel concentration. However, there is no drinking water standard for nickel.

The lead concentration in the ground water was at the drinking water standard prior to ash disposal and varied above this level after the ash disposal in all four wells. It must be noted that this increase in lead concentration occurs in well 101, which is up-gradient of the ash disposal site and well 106, where leachate from the ash should not have migrated to this well within the time period since the ash disposal. This apparent change in the water quality from the four wells also occurred with the zinc concentration. Water from wells 101 and 106, neither of which should be affected by the ash, showed greater increases in zinc concentrations than did water from wells 102 and 104.

Assuming that the monitoring well's samples were representative of the ground water and the wells were properly placed in the leachate plume from the ash, the increase in the concentrations of metals in wells 101 and 106 suggests that the apparent ground water quality changes could be from a different source than the ash. Given the complex nature of the soil and landfill system and the interacting factors, it would be difficult to determine what is the exact mechanism and cause of the indicated ground water quality changes, but a few possibilities are briefly discussed.

The ground water monitoring data shows that the pH of the ground water is gradually decreasing. The lowering of pH could result in the increase in the solubility of certain metal species that were already contained in the landfill. The decrease in pH appears to occur in well 101 before the other wells. Since well 101 is up-gradient of the ash disposal site and is highly influenced by water in Battle Creek, suggests that acidity could be flowing into the ash area and due to another source than the ash. This water would be from surface runoff from areas north of the landfill, such as the railroad yard. (see Figure 1). This surface runoff could contain acidic materials or various metals that were measured in the ground water.

The decrease in pH could also be the result of increased biological activity in the landfill due to fluctuating ground water levels. It should be noted that the ash has a high lime content, which would decrease the pH of leachate percolating through the ash.

increase

The pH of the distilled water that was passed through the ash in the leachate test described earlier, was raised to 10.85 (Table 2). The addition of the ash to the top of the landfill should, therefore, have reduced the mobility of metals originating from the landfill. This could be a possible explanation for the lower apparent changes in zinc concentrations in water from wells 102 and 104, compared to wells 101 or 106. However, the pH in all four wells appears to decrease about the same extent.

Another possible source of the indicated ground water quality change is fluctuating ground water levels resulting in oxidation-reduction reactions that could increase the mobility of various metals. Also, since the abandoned landfill contains industri l wastes, chemicals could be originating from this source.

In summary, the increase in certain metals concentrations in wells that should not have been impacted by the ash (wells 101 and 106), suggests that the indicated water quality changes could be due to a source other than the ash. In addition, the magnitude of the apparent change in ground water quality is probably of reduced importance considering that the ground water quality did not meet drinking water standards prior to ash disposal. The mercury and zinc concentrations in water from the wells appear to increase, but generlly stay below even the recommended drinking water standards. Given that mercury is measured in the part per billion range, it is also possible that the variations in mercury concentration is due to analytical variations.

The location of the proposed ash disposal project and the capacity of this disposal environment to assimilate waste without degrading the quality of the off-site environment is consistent with Solid Waste Guide chapter policies.

2. The environmental monitoring program conducted at the landfill appears adequate to properly evaluate contaminants migrating from the site. Currently, the MWCC monitors ground water levels and quality from four wells in the ash disposal site (wells 101, 102, 104 and 106). The location of these wells are shown in figure 2. In addition, some historical ground water levels and quality data have been available from wells established by the Soil Exploration Company during investigations for a proposed coal handling facility.

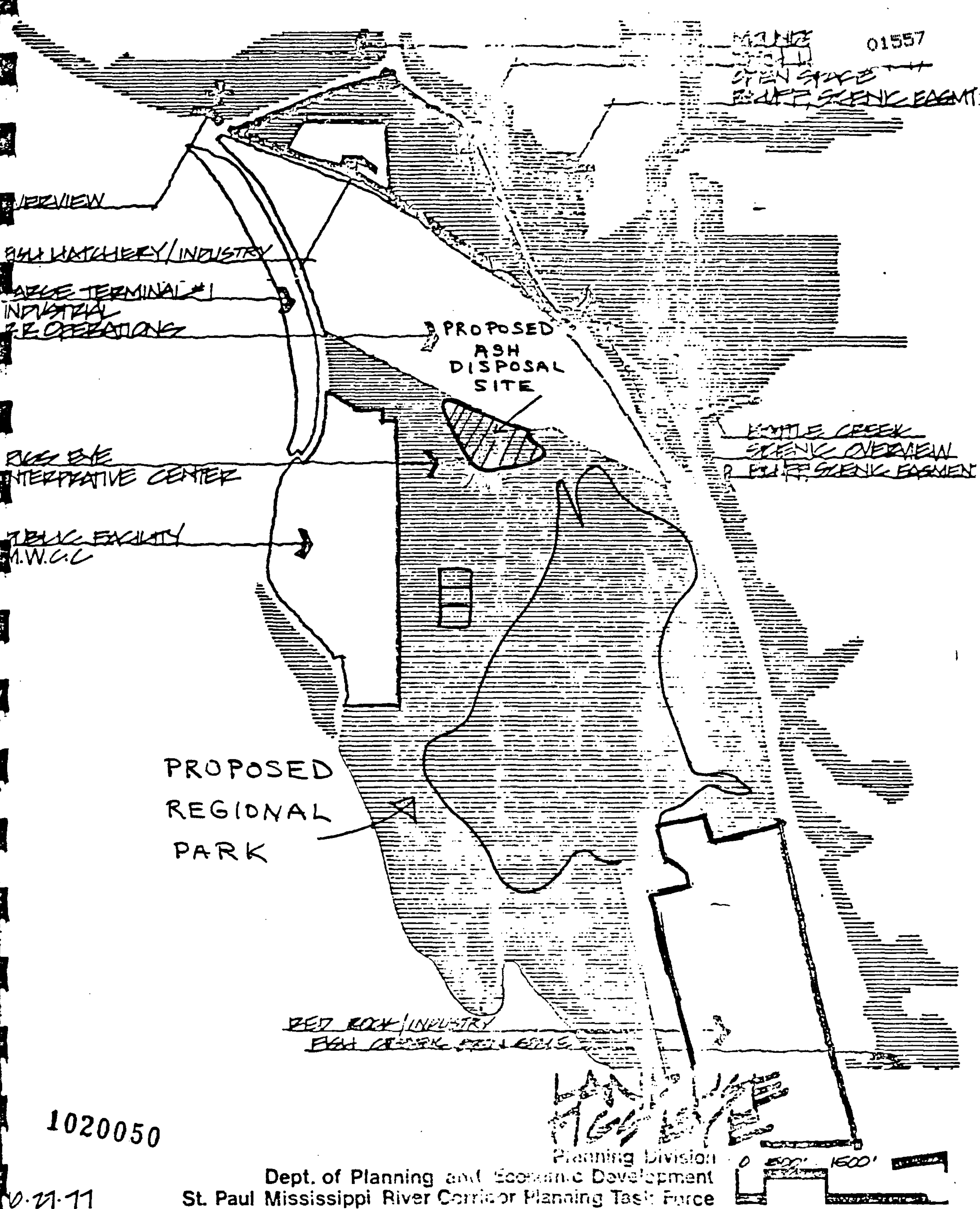
Presently, wells 101, 102, 104 and 106 are sampled quarterly for pH, alkalinity, mercury, cadmium, zinc, lead, nickel, copper, total chromium, ammonia and hexavalent chromium. The test results from these samples are evaluated by the MPCA.

3. Alternatives to the proposed project are discussed later in this report.

4. The proposed ash disposal project is consistent with local solid waste and land use plans affected by the project. Ramsey County is currently in the process of preparing its solid waste master plan. The proposed ash disposal project does not preclude or adversely affect solid waste policy decisions that will be made in the future concerning preparation of the county's master plan.

B. Consistency with St. Paul Critical Area Plan

01557



1020050

Planning Division
Dept. of Planning and Economic Development
St. Paul Mississippi River Corridor Planning Task Force

St. Paul Mississippi River Corridor Plan

Figure 3

Under the Critical Area designation the Pig's Eye Lake Area has been designated as an Urban Open Space District to conserve and protect the existing and potential recreational, scenic, natural and historic resources and uses for the use and emjoyment of the surrounding region. The requirements for this district and the Critical Area Interim Development Regulations apply to all proposed developments until the City of St. Paul adopts plans and regulations which have been approved by the EQB. Also the Executive Order sets a specific standard for the Pig's Eye Area which states "The City of St. Paul shall prepare plans and regulations to balance open space, industrial and commercial developments ...".

According to the proposed St. Paul Critical Area Plan which the Metropolitan Council reviewed in January, 1980, the ash disposal site will be located within the boundaries of the Pig's Eye regional park. See Figure 3. The City of St. Paul has not as yet taken any official action on the proposed ash disposal. The City Planning Commission will be reviewing the proposed local conditional use permits for the ash disposal at its meeting and public hearing on March 6. The results of that meeting will be made available to the Physical Development Committee for its hearing on March 13, 1980. The city planning staff has indicated informally that there does not appear to be any significant concerns about the ash disposal as of this date. At the time of the previous permit the city expressed some concern about the capability of the ash fill and cover to support plant material and particularly the eventual re-establishment of trees on the site. At that time the city felt that the underlying landfill materials would be a greater problem in attempting to establish trees. In the two years since the initial ash disposal the seeding of the site has resulted in the development of a dense growth of grasses and other vegetation.

Ramsey County has been designated in the Regional Recreation Open Space Plan as the implementing agency for the Pig's Eye Regional Park. Copies of the proposed ash disposal project were submitted to the Ramsey County Parks and Open Space department staff for their review. The staff has indicated informally that they have no major concerns about the impact of the proposed project on the regional park.

Based on the comments of the Ramsey County Parks and Open Space and St. Paul city planning staff the proposed project would have minimal effect on the proposed regional park and the city's Critical Araea plan for the area.

C. Potential Degradation of Surface Waters

The potential impact on ground water quality has been discussed thoroughly under the section "Consistency with Solid Waste Management Chapter." This short section will focus on the floodplain location of the disposal site and examine the potential impacts of runoff on surface waters in the area, i.e. Battle Creek and Pig's Eye Lake.

Under the Critical Area designation lands and water in the Urban Open Space district are to be "managed to conserve and protect the existing and potential recreational, scenic, natural and historic resources ..." The Interim Development Regulations set specific requirements for grading and filling in all districts to protect surface waters from sedimentation.

The proposed site is located in the flood fringe area of the designated floodplain. The 100-year flood level is at an elevation of 706 feet above sea level at this location. The completed elevation of the disposal site will range from 702 to 708 feet above sea level. A portion of the completed site could be "inundated" during flood periods. During the public hearing and review of the previous ash disposal project the DNR staff testified that there would be insignificant flood water velocities at the site during flood levels. The conclusion at that time was that if the site were covered with clayey soils and a vegetative cover were established as soon as possible, the project would not present serious floodplain management concerns. The current ash disposal project is in the same general floodplain location, and the Metropolitan Waste Control Commission has indicated that six inches of top soil will be applied and the area will be seeded as soon as final grading is completed to minimize future erosion problems. Daily cover will be applied if the ash is spread during non-freezing conditions. Daily compaction of the cover materials will further minimize the erosion potential. Also, MPCA regulations require that surface runoff be managed to minimize erosion at all landfill sites.

State and local permitting agencies should be assured that adequate measures are utilized to minimize the erosion of the cover materials and ash during and following completion of the project. A permit for grading and filling is required under the Critical Area Interim Development Regulations. Specific standards for erosion control are to be met in granting the permit.

D. Alternatives to the Proposed Action

Along with its approval of the initial ash disposal project in 1977 the Metropolitan Council recommended that "the MWCC analyze daily alternative uses and methods for disposing of ash materials for the period to 1981 and their environmental and economic impacts." It was assumed that the improved facilities at the Metro Plant would be completed by 1981 and the lagoons would no longer be needed. During the interim period the Metropolitan Waste Control Commission has been examining various immediate solutions to the disposal of the ash particularly until implementation of a long-term management system can be achieved. In May 1977 the Commission authorzed the preparation of a residuals management study as part of its 201 facilities planning effort. The study included an analysis of and recommendation for interim systems to cover that period before 1982 when a long-term residuals management system would be implemented. The results of that study were published in the report Residual Solids Management Study - Analysis of Immediate Needs May, 1978.

The residuals management study concluded that for the immediate future landfilling is the only method with any assurance of reliability and implementation. At present there is no dependable alternative use on a large scale. Possible use of incinerators are being investigated as part of a long-term management plan. The other aternatives considered in the study included expansion of thhe previous ash disposal site on the former St. Paul landfill, expanding the volume of the temporary storage basins at the Metro Plant, and commercial landfilling. The ash would be confined in a separate area of the landfill or used as a base cover prior to the placement of top soil and seeding similar to the current project. The study recommended that the former landfill site be used to dispose of ash from one basin to allow the MWCC time to implement an alternative system for the immediate needs period to 1982 using either of the two latter methods.

The MWCC staff has indicated that the agency will apply for permits in the near future to expand the capacity of the temporary storage basins. There will then be adequate basin capacity to temporarily store the ash until 1983. The staff estimates that by 1983 the MWCC will have selected and have in operation a site for a separate landfill to meet the long term needs for ash disposal. Commercial landfills have not been available for ash disposal for several years due to MPCA regulations which prohibit the ash from being mixed with other solid wastes in a common area. This is based on a concern that the acidic conditions in other solid wastes would permit the metals in the ash to go into solution and leach into the ground water. The MWCC staff indicates that landfill operators have refused to landfill the ash separately. Because of the lack of alternative uses and other methods such as temporary storage space for disposing of the ash at this time, the disposal of the ash on the former St. Paul landfill appears to be the only viable solution at this time.

V. Conclusions-

1. The proposed project is consistent with the Metropolitan Council's Solid Waste chapter of the Metropolitan Development Guide.

2. The proposed project is consistent with the City of St. Paul's Critical Area plan for the Pig's Eye Area and the proposed Pig's Eye regional park.

3. The proposed project is consistent with the requirements of the Critical Area Urban Open Space district for development in the Pig's Eye area. The project and proposed measures will protect the waters and lands in this district.

4. The project is consistent with local and state floodplain management standards requirements.

5. The measures required by the MPCA and Critical Area Interim Development Regulations will prevent erosion of the ashes and soil cover. The Interim Development Regulations require that specific erosion control standards be met in order to secure a grading and filling permit.

6. There are currently no viable alternative uses or sites for the immediate disposal of the incinerator ash. The MWCC is presently studying a long-term disposal plan for the ash to be implemented by 1983.

VI. Recommendations

1. That Metropolitan Council approve the Metropolitan Waste Control Commission's solid waste permit application to the Minnesota Pollution Control Agency for the disposal of incinerator ash in the Pig's Eye Lake area on the site of the former St. Paul landfill.

2. That Metropolitan Council recommends to the EQB that the proposed disposal of incinerator ash in the Pig's Eye Lake area on the former St. Paul landfill be found consistent with Critical Area requirements for development in the Urban Open Space district.

3. That the solid waste permit issued by the MPCA for the proposed incinerator ash disposal project be conditioned to provide for the daily application and compaction of 6" of cover material to the working area of ash disposal and seeding of the project area upon completion of the final grading.

CH749A

DOCUMENTS RELATING TO:

THE SHAFER CONSTRUCTION COMPANY (EXHIBIT C.3)

01563

Joe
File - MWCC
Core

DEPARTMENT OF THE ARMY
ST. PAUL DISTRICT, CORPS OF ENGINEERS
1135 U. S. POST OFFICE & CUSTOM HOUSE
ST. PAUL, MINNESOTA 55101

REPLY TO
ATTENTION OF:
NCSCO-GR(77-143-27)

11 January 1978

Mr. Louis Flynn
Minnesota Pollution Control Agency
1935 West County Road B2
Roseville, Minnesota 55112

Dear Mr. Flynn:

An investigation conducted by the Corps of Engineers has revealed that Shafer Construction Co. of Forest Lake, Minnesota, while working under a contract with the Metropolitan Waste Control Commission, placed fill for a haul road in a wetland adjacent to Pigs Eye Lake in Section 10, Township 28 North, Range 22 West in Ramsey County, Minnesota.

No Department of the Army permit has been issued to the Metropolitan Waste Control Commission authorizing placement of fill material in wetlands adjacent to Pigs Eye Lake. The said activity is in violation of Section 301 of the Federal Water Pollution Control Act Amendments of 1972.

In order to assure that a thorough public interest review of this matter is conducted and to promote to the most practicable extent the consistent application of Federal, State and local regulatory guidelines, we request that your office forward comments it may have relative to the unauthorized activity.

We would appreciate your comments specifically addressing such considerations as follow:

a. Impacts and significance of the unauthorized activity;
b. Authorization or approval, if any, previously granted by your agency;
c. Desirability or feasibility of restoration;
d. Applicability of interim protective measures;
e. Applicability of criminal or civil sanctions;
f. Desirability of accepting an after-the-fact permit application.

1010058

It should be noted that a combination of these remedies is generally available and that restoration and/or criminal and civil sanctions are available if an after-the-fact permit is denied. Also, if restoration or interim protective measures are recommended, we request that the nature and extent of the remedial measures be specified.

Since the work is of a nature where delay in our handling of this case could be prejudicial, we request your comments within thirty (30) days from the date of this letter. If a response is not received by that time, we will assume you wish to make no comments.

Should you have questions in this matter, please contact this office at the above address or call Richard Howard at (612) 725-7976.

Sincerely,

William D Parsons

WILLIAM D. PARSONS
Chief, General Regulatory Branch
Construction-Operations Division

01565

1010056

DOCUMENTS RELATING TO:

THE ST. PAUL WATER DEPARTMENT (EXHIBIT C.4)

Call Ho[illegible]

— [illegible]

01567

June 16, 1978

William Meuissen
St. Paul Water Department
277 North Hamline Avenue
St. Paul, MN 55104

Dear Mr. Meuissen:

As discussed during our telephone conversation of June 15, 1978, it has come to the attention of this office that refuse has been excavated from the abandoned Pig's Eye landfill and placed in a wetland located east of the tree chipping facility at Pig's Eye.

As you are aware, the United States Corps of Engineers is requiring removal of this material from the wetland.

Please be advised that the Pig's Eye landfill has been certified closed by this office. Therefore, excavated refuse cannot be disposed of at the landfill unless a permit therefor is issued by the Agency. Since it is unlikely that Agency staff would recommend permit issuance for such a project to the Agency board, it would appear that hauling the refuse to an Agency permitted solid waste disposal facility is the only feasible method for disposal of this material.

Thank you for your cooperation on this matter.

Yours very truly,

Daniel A. Comeau
Soil Scientist
Permits Section
Division of Solid Waste

DAC:nw
bcc: TPC, BWB, LLD
Rich Howard, Copps of Engineers
Mike Mueller, MDNR
Dan Schacht, Ramsey Co. SWO

296-7324

2000108

Water Dept. Rob Cihlar

298-4122

Port Authority owns
property along with

Parks + Recreation

01569

DOCUMENTS RELATING TO:

WHIRLPOOL CORPORATION (EXHIBIT C.5)
SELBY DISTRICT COMMERCIAL ______ (EXHIBIT C.6)
RAMSEY COUNTY RECREATION DEPARTMENT (EXHIBIT C.7)
PHALLEN AREA COMMERCIAL COUNCIL (EXHIBIT C.8)
EAST SIDE COMMUNITY (EXHIBIT C.9)
MADEL NEIGHBORHOOD BEAUTIFICATION (EXHIBIT C.10)
DAYTON'S BLUFF COMMUNITY CENTER (EXHIBIT C.11)

01570

I-8

File

TO: Joe Crea

FROM: Kent Schonberger

DATE: October 13, 1971

SUBJECT: QUESTIONS RAISED RELATIVE TO WHIRLPOOL CORPORATION'S REFUSE MATERIAL

Ed Hartung who is an engineer with the Whirlpool Corporation on Payne Avenue (phone 776-8511) called me on October 12, 1971 to state that the contractor who handles the waste disposal for Whirlpool had conveyed back to Mr. Hartung that there had been some questions raised at the landfill relative to the nature of the material which was being disposed of.

Mr. Hartung states that questions were raised by someone at the landfill as to the advisability or legality of disposing of what he calls "porcelain and paint sludge material". He says they dispose of no more than 15 to 20 barrels of such material on the basis of one to three months. He says these are not toxic materials and almost completely solid rather than liquid.

The porcelain material, he says, is a totally inert substance that is like a crushed or chipped glass material and has less than a 2% moisture factor. The paint sludge material, he says, is actually the residue left after cleaning out the recycling pumps used for painting and, he says, there is actually very little water in that. Since these are not flammable materials, nor are they toxic materials, he is wondering why the question is being raised about bringing this material to the landfill.

Since all I have to go on is what he tells me, I would appreciate your looking into this further and determining whether the amount of material, the nature of it, etc. is as he says or is different, and what your recommendations are with regard to the handling of it. If it is as he says, I see no problem to it, but if it is different, please let me know at your earliest convenience.

KS/em

DEN

10-21-71

see attached reply from Joe Crea. I phoned Hartung this date and told him we had no objection to above material but only to closed drums containing flammables, explosive or toxic chemicals, etc.

KS

From the desk of

JOSEPH CREA

10/15/71

To = Don Nygaard
Subject = Whirlpool Corp. Refuse

As per your communication of Oct. 13th. I am satisfied that the materials mentioned pose no problem for us, and the material I am concerned with is the closed drums containing paint thinner which almost caused a burnt dozer and loss of operator at our last fire. This load began burning and as soon as our dozer tried to push the barrels away from the fire it exploded and flames started burning on the Hydraulic Arms and undercarriage of dozer # 428. The exploding barrel flew up into the air breaking one front Glass and narrowly missing

01571

From the desk of

JOSEPH CREA

01572

our operator Ed. Lindstrom.
Luckily, the fire dept. was alongside him and was able to drown the flames.

I then asked all haulers of drums to discontinue delivery of any closed drums or drums with oil in them.

This included Waste Control, McKnight, and Casanova Bros, and Poor Richards.

This for your Information
J. A. Crea

01573

FILE

TO: EUGENE VERDICK

FROM: DONALD E. NYGAARD

DATE: FEBRUARY 27, 1973

SUBJECT: TRASH AND RUBBISH STREWN AROUND ENTRYWAY TO OLD PIG'S EYE LANDFILL

I mentioned this to you on the radio Tuesday morning, February 27th, but I'll follow it up with a brief memo. I noticed this morning that there is a considerable amount of rubbish strewn along the east side of the roadway adjacent to the gate at Pig's Eye. Very likely this rubbish has been there for some time but, I expect, because it is there people add to it from time to time.

I'd like you to route a few compactor trucks down there at the end of the day over a period of two or three days to get the rubbish cleaned up, then, please post a "no dumping" sign at that location.

Thanks, Gene.

DEN/em

Free dumping 1971

April 18 thru 24 - "Cleanup week"

	3,994 vehicles	11,541 cy
May 17, 18, and 22 -	8 "	74
	total	11,615 cy

East Side Community Center	275 c.y
Model Neighborhood Beautification	329 cy
Daytons Bluff Community Center	68 cy

~~April 24~~

~~Free dumping day.~~

01574

Free Dumping

1970

April 25th "Clean Up Day"

~~4th~~ July 11th - "Operation Cleansweep"

Free Dumping 1969

May 15th thru 19th , Vehicles 6,313 c. yd. 3,475

May 20th.
(at Pigs Eye sponsored by Selby district Commercial Cl
17 ~~veh~~ vehicles 275 c.y.

Also in May of 1969 - Ramsey County Recreation Dept.
4 vehicles 48 c.y.

Also, May, 1969 - Phalen Area Commercial Comm
Youth Employment Div
9 vehicles 98 c.y

~~Start~~ July thru 29th STORM DAMAGE (Pondaday
1,672 vehicles 19,960 c.

0157

Free Dumping 1968 at Fish Hatchery ONLY

April	22	
"	23	
"	24	total 430 cu yds.
"	25	
"	26	

Free Dumping

1967

	Vehicles	total Cu yd.
May 15	1,830	993 cu yd.
" 16	933	444 " "
" 17	855	474 " "
" 18	1,462	720 " "
" 19	1,233	844 " "

DOCUMENTS RELATING TO:

MINNESOTA MINING & MANUFACTURING (EXHIBIT C.12)
HAUL-A-WAY SYSTEM (EXHIBIT C.13)
McKNIGHT BROS. (EXHIBIT C.14)

M E M O

Fred E. Edlund, Supervisor
Minnesota Mining & Manufacturing
Pr 6-8811, Ext. 6134

Asked for permission to dump daily rubbish at Pigseye Landfill, that they have been hauling to private property off Highway #94 known as Harry McNealy Farm. Said there would be a total of 9 to 10 loads daily with about 4 coming from Chemolite Plant, or 20-25 loads weekly. Loads to be delivered after 7:00 a.m. and before 4:00 p.m. daily except Sunday. I proposed charge of $300.00 per month, which was subsequently accepted as of April 1, 1961. (See copy of agreement and Council permit dated 4-1-61 - payable monthly in advance.)
On a ck. made during Aug '61, There were 253 loads hauled in from St. Paul & Hastings. 4 loads daily from Hastings.

West St. Paul pays $100.00 per month for 20 yards per week, payable January 1 annually, ~~b~~ in advance, agreement dated December 21, 1960.

Haul-A-Way System (Dean Meredith) - $25.00 per month for 5 yards a week. Agreement dated October 20, 1961, payable semi-annually in advance, Jan 1st & Jul. 1st.

McKnight Bros., So. St. Paul - $10.00 per month for 4 yards a week. Payable Jan 1st Anl. in advance.

DOCUMENTS RELATING TO:

THE CHICAGO, MILWAUKEE, ST. PAUL
& PACIFIC RAILROAD (EXHIBIT C.15)

01580 KENT FILE

I-8

THE DEPARTMENT OF PUBLIC WORKS
OF THE
CITY OF ST. PAUL

INTER-OFFICE COMMUNICATION

February 28, 1969

FILE MEMORANDUM

RE: MILWAUKEE RAILROAD'S REFUSE AT PIG'S EYE LANDFILL

DEN spoke with Mr. Roy Johnson from the Milwaukee Railroad on Friday morning, February 28, 1969 concerning the Milwaukee Railroad's dumping at the Pig's Eye Landfill.

Mr. Johnson stated that their truck had gone to the Pig's Eye this morning and that the attendants would not allow them into the Landfill. This was a misunderstanding on our part in that Kent's memo had not yet arrived at the Landfill. I discussed the memo with Vern Tester and even though the Milwaukee Railroad is hauling some wood and timbers, etc., the Milwaukee people feel that they have a right to dump this at Pig's Eye. Rather than make a big issue over this, I told Vern Tester to allow them to go ahead and dump at the Pig's Eye. (I would appreciate it if Joe Crea at his convenience would get ahold of Mr. Johnson and probably work out some better understanding on this.)

Mr. Johnson also made a point of the fact the Twin City Waste Disposal hauls some for the railroad, possibly 8 or 9 loads a year and he feels that we should not charge for this stuff that is coming from the railroad. I told him that if they could put one of the Milwaukee Road's stickers on that particular truck so that our people could identify it, that we would then admit it free to the Pig's Eye Landfill. I talked to Vern Tester about this also and our people will go ahead on this basis. month ?

I could tell in talking to Mr. Johnson that they are getting a little bit upset about this since it is their land, etc., and rather than make a big issue out of these things, I think it's best that we try to cooperate even though we have to do some things that don't conform exactly to our policy.

This is for file purposes.

DEN

DONALD E. NYGAARD
CIVIL ENGINEER III
MAINTENANCE SERVICES DEPARTMENT

DEN:em

cc: Joseph Crea

01581

V

TO: Joe Crea

FROM: Kent Schonberger

DATE: February 27, 1969

SUBJECT: Further information relative to Milwaukee Railroad refuse being dumped at Pig's Eye Landfill

Mr. Johnson from the Milwaukee Railroad called me on February 25, 1969, the same day that I received your memo with regard to the circumstances about which he was asking.

I told Mr. Johnson, as confirmed in your note, that we could see no reason for having hold ups or delays in connection with their trucks dumping at Pig's Eye and also that we would not have any objection to them bringing in some lumber, especially if this is being deposited in areas which the Milwaukee Railroad gave us for dump operations.

Insofar as bringing the location in at a gate or driveway off their property, Mr. Johnson feels this is not necessary inasmuch as they would come through the normal Pig's Eye access road. This way their own identified truck would be coming in and I'm sure other than for record keeping purposes, you would let it in then without any charge for such dumping on the earlier stated basis of about four loads per day.

Mr. Johnson also told me that they often hire a private contractor, possibly Twin City Waste Disposal, to haul some material from an area further down toward their humping yards and that this amounts to about nine 17 yard compactor loads per month, or an average then of about one every second or third day. He told me that at the present time the firm hauling this apparently is paying the entrance fee and in turn the Railroad is being billed this amount and he asked whether or not an arrangement could be made for the Railroad to be rebated that money. I explained that any type of rebate would be an almost impossible thing once the money was within the City financial umbrella, but that if we had some completely clear and positive means of identifying who was bringing the material and that only those loads which came from the Milwaukee Railroad would be allowed in, arrangements could likely be made between you, Mr. Johnson and the firm doing the hauling for a positive means of identification, perhaps by some special tickets, signed slips or the like, we would allow the private firm trucks hauling from the Milwaukee Yard properties only to come into Pig's Eye also via the normal roadways and gate at no charge. Mr. Johnson will look further into this matter and be in further contact with you or me. This for your information.

KS

KS:ma
DEM

From the desk of

JOSEPH A. CREA

2/25/69

01582

To: Kurt Schonberger

From: Joseph A. Crea

Subject: Dumping of Railroad material on Pigs Eye Landfill

Several years ago, an agreement was made between our department and the Milwaukee R.R. in effect, we would provide an entrance area in close proximity to the bridge area over battle creek. This agreement was verbal and after we had provided a entrance area it was my understanding that the R.R. engineers refused this, as the material was <u>not</u> suitable

From the desk of

JOSEPH A. CREA

01583

for filling their land.
They then hired a private concern to haul their material away and the hired concern hauled it around to our area.
The amount of wood content and type would not be unacceptable to us. The agreement for disposal of this material by burning was a condition by the Milwaukee R.R. for use of the land and since burning was no longer allowed, we discontinued dumping of this material at Pigs Eye. We must realize that this area is the property of the Milwaukee R.R. and if they have no objection to this type of wood, then we have no objection

From the desk of

JOSEPH A. CREA

01584

I would mention that, sho the R.R. begin disposition of these materials at Pigs Eye, that some work would be necessary on the entrance road from their right of way.

The mention of having their truck held up from dumping is without foundation.

There is no gate along their right of way. Mention of this matter was formally made to the railroad at the time of discussion for entrance near the bridge to stop personels from bringing their household rubbish and from illegal trespassing. However, no gate was ever installed.

01585

File

TO: Joe Crea

FROM: Kent Schonberger

DATE: February 24, 1969

SUBJECT: Dumping problems of the Milwaukee Railroad Yard adjacent to Pig's Eye

This office was contacted by Mr. Roy Johnson, Division Engineer for the Milwaukee Railroad, phone 339-4178, who stated that as mentioned in the letter of Dr. Cox about two months ago, there have been complaints by the Health Department about the dumping operation done by the Milwaukee Railroad down in the vicinity of their hump switch area because of the open debris and the lack of cover, as well as no permit existing for such dumping.

Mr. Johnson states that they wish to eliminate this dumping complaint and completely end any disposal of material from their so-called rubbish track in that area. He states their total debris is about four small truck loads per day, which he estimates in the vicinity of 20 to 25 cubic yards total.

He says that his people have informed him that there are two basic problems which have tended to prevent them from doing their dumping within the Pig's Eye Landfill, for which it is my understanding a gate or opening is provided so that they can go directly into the landfill without having to drive around to our normal access gate. He states that (1) their operating people have told him that when the trucks come to Pig's Eye, they have to wait a considerable length of time in line to dump and with only one truck, they do not have waiting time. This seems somewhat unusual to me in the few times I have been down there there is very little, if any, wait with most of the trucks I have observed; (2) he states that they have a certain amount of lumber or timbers used in the doors of the boxcars and this lumber material has been objected to by some unknown parties, supposedly at Pig's Eye.

At your convenience could you let me know what the story is on this waiting to dump situation, whether this is anything of any consequence and if so, in view of their relatively small volume and the fact they are leasing some of this area to us, whether we could give them some priority to insure no wait. Secondly, could you let me know whether this timber material has been any situation where our people have stopped them from dumping or whether the Railroad people are confusing this with dumping at possibly some other site which was prohibited by the Health Bureau or some other agency. Also, whether you think the proportion of small wood pallets or other lumber which they would bring in would be something which we should not permit or whether this meets the terms of the present lease arrangements we have for Pig's Eye.

If lumber quantity is very great, what about letting them dump at Fish Hatchery instead of Pigseye?

I would appreciate your assembling this information as soon as convenient and furnishing this in a written form, if at all possible, to Don or me and we can arrange to contact Mr. Johnson once we have your reply. Thank you.

KS

KS:ma
DEN

From the desk of

JOSEPH A. CREA

7/16/69

To - Kent Schonberger
Subject - Revision of Landfill Agreement between City of St Paul and C.M. St Paul R.R.

The attached maps will show areas and owners of parcels located at Pigs Eye Lake.

We must remember that on May 26, 1969. an agreement was made with the Milwaukee Railroad for free disposal of materials from their Cleanout Cars. and to date the following amount of yardage was disposed of at Pigs Eye Landfill without cost to the Milwaukee R.R.-

From the desk of

JOSEPH A. CREA

5- 10 cubic yard trucks daily for 5 days = 250 cubic yards @ .25 per cubic yard. = $62.50

4- 10 cubic yard trucks on Sundays 1 day = 40 cubic yards @ .25 per cubic yard = $10.00

2- Semi's at 40 cubic yards each dumped on Saturdays = 80 cubic yds @ .25 per yd. = $20.00

Total weekly trucks and yardage = 32 truckloads and 370 cubic yds

If collection was made it would equal = $92.50 per wk.

Dumping free since May 26, 1969 through July 20, 1969 would equal 8 wks, and total cost would have been $740.00

This for your information

EXHIBIT D

THE PLAN AND ORDER NOS. 809, 832 AND 866

NOTICE OF PLAN APPROVAL AND CONFIRMATION

To: Creditors and Stockholders of the Chicago, Milwaukee, St. Paul and Pacific Railroad Company, Debtor, in Proceedings for Reorganization under Section 77 of the Bankruptcy Act.

On May 1, 1985 the Trustee of the property of the Chicago, Milwaukee, St. Paul and Pacific Railroad Company, Debtor, filed with the United States District Court for the Northern District of Illinois, Eastern Division (the "Court") his 1985 Plan of Reorganization (the "Plan") for the Debtor. Hearings with respect to the confirmation and approval of the Plan were held by the Court on June 24, 25, 27, 1985 and on July 12, 1985. On July 12, 1985, the Court entered its Order No. 832 modifying the Plan and confirming and approving the Plan as modified. The Plan as modified is attached to this Notice.

Any inquiries with respect to the Plan as modified should be directed to the Trustee at the address indicated below.

By Direction of the Court

RICHARD B. OGILVIE
Trustee of the Property of the
Chicago, Milwaukee, St. Paul
and Pacific Railroad Company,
Debtor
547 West Jackson Boulevard
Suite 1510
Chicago, Illinois 60680-6205
(312) 294-0480

ROBERT H. WHEELER
Counsel to the Trustee
ISHAM, LINCOLN & BEALE
Three First National Plaza
Suite 5200
Chicago, Illinois 60602
(312) 358-7500

Dated: July 29, 1985

IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF ILLINOIS
EASTERN DIVISION

IN THE MATTER OF
CHICAGO, MILWAUKEE, ST. PAUL
AND PACIFIC RAILROAD COMPANY,
DEBTOR

IN PROCEEDINGS FOR THE REORGANIZATION
OF A RAILROAD

Docket No. 77 B 8999

The Honorable Thomas R. McMillen, Judge Presiding

TRUSTEE'S MODIFIED 1985 PLAN OF REORGANIZATION
(As Approved and Confirmed By Order 832)

RICHARD B. OGILVIE, Trustee
547 West Jackson Boulevard
Suite 1510
P. O. Box 6205
Chicago, Illinois 60680-6205

July 12, 1985

TABLE OF CONTENTS

I. DEFINITIONS

As used in this Plan of Reorganization with initial capitalization, the following words have the meanings set forth below, except where a different meaning is clearly indicated or required by the context:

1.1 "*Allowable Claim*" means a Claim which is ultimately determined by the Court to be properly payable out of the Estate under applicable law, including interest in the amount, if any, provided by the Plan or allowed by the Court.

1.2 "*Asset Purchase Agreement*" means the agreement between the Trustee and Soo dated April 6, 1984, as amended, which provided for the acquisition of the Debtor's operating rail system by Soo.

1.3 "*Bankruptcy Act*" means the Bankruptcy Act of 1898, as amended.

1.4 "*Claim*" means a claim against the Trustee in his capacity as Trustee, the Debtor or the Estate as defined in Section 77(b) of the Bankruptcy Act (including claims arising under certificates issued pursuant to Section 77(c)(3) of the Bankruptcy Act and claims for fees and expenses under Sections 77(c)(2) and 77(c)(12) of the Bankruptcy Act), whether arising Post-Petition or Pre-Petition.

1.5 "*Confirmation Date*" means July 12, 1985.

1.6 "*Consummation*" means the carrying out of all acts and procedures contemplated by the Plan, commencing with the Confirmation Date.

1.7 "*Consummation Date*" means the date fixed by order of the Court on which legal and beneficial ownership of the Estate's assets will be vested in the Reorganized Company.

1.8 "*Court*" means the United States District Court for the Northern District of Illinois, Eastern Division, which has jurisdiction over the Debtor's reorganization proceeding.

1.9 "*Debentures*" means the Debtor's 5% Income Debentures, Series A, due 2055, issued pursuant to an indenture dated January 1, 1955 ("Indenture").

1.10 "*Debtor*" means the Chicago, Milwaukee, St. Paul and Pacific Railroad Company, a Wisconsin corporation, which is in reorganization under Section 77 of the Bankruptcy Act, in the Court's Docket No. 77 B 8999.

1.11 "*Distribution Date*" means a date fixed by the Trustee for distribution to claimants of a particular class in accordance with Section 5.2 of the Plan.

1.12 "*Estate*" means all of the Debtor's assets, businesses and properties which are subject to the Court's jurisdiction in this reorganization proceeding.

1.13 "*Plan*" means this 1985 modified plan of reorganization.

1.14 "*Post-Petition*" means the period subsequent to the filing of the petition to reorganize the Debtor on December 19, 1977 and prior to the Consummation Date.

1.15 "*Pre-Petition*" means the period before the filing of the petition to reorganize the Debtor on December 19, 1977.

1.16 "*Reorganized Company*" means the Debtor, with appropriate amendments to its articles of incorporation to change its corporate name, which will be vested with the assets of the Estate pursuant to the Plan on the Consummation Date.

1.17 "*Segregated Account*" means the escrow account described in Section 5.7 of this Plan established for the purpose of securing payment of Allowable Claims after the Consummation Date.

1.18 "*Soo*" means collectively the Soo Line Railroad Company, a Minnesota corporation, and its affiliate The Milwaukee Road Inc. (formerly SLRCO, Inc.), a Minnesota corporation.

1.19 "*Trustee*" means Stanley E. G. Hillman, qualified as Trustee on February 13, 1978, as succeeded by Richard B. Ogilvie on August 20, 1979, in their respective capacities as trustees of the property of the Debtor, and each duly-appointed successor.

II. INTRODUCTION

On February 19, 1985, the Soo acquired pursuant to the Asset Purchase Agreement the Debtor's operating rail properties for $192,000,000 in cash and the assumption of approximately $395,000,000 in long-term and other liabilities calculated on an Interstate Commerce Commission Accounting Basis. The cash portion of the purchase price is subject to certain retroactive adjustments which the Trustee estimates will not in the aggregate be material. The sale to the Soo represents the culmination of the disposition of the Debtor's operating railroad properties, other than approximately 85 miles of track and right of way situated in the Chicago, Illinois vicinity, which are operated by the Soo for freight service and the Northeast Illinois Regional Commuter Railroad Corporation for commuter service. The Trustee and the Debtor have no continuing obligations for the operation of any rail services. The proceeds realized by the Trustee from the sale to the Soo, coupled with assumption by the Soo of approximately $395,000,000 in obligations, has permitted the Trustee to propose this Plan, which if consummated will result in the discharge of the Debtor from reorganization after providing for the full payment in cash of all Allowable Claims. The Plan contemplates substantial completion of the reorganization proceedings by December 31, 1985.

2.1 History of the Proceeding

On December 19, 1977, after three years of heavy losses, the Debtor, a Class I transcontinental railroad, filed its petition for reorganization under Section 77 of the Bankruptcy Act. At that time the Debtor operated a system of nearly 10,000 route miles in the Midwest and across the northern tier states to the Pacific Northwest. The petition was approved on December 20, 1977 and Stanley E. G. Hillman was appointed as Trustee on February 13, 1978. Mr. Hillman was succeeded as Trustee by Richard B. Ogilvie on August 20, 1979.

Subsequent to filing for reorganization, the Debtor continued to sustain heavy losses. In 1979 Mr. Ogilvie determined that the revitalization of the entire 10,000-mile system was not practical. Accordingly, in that year the Trustee, under the direction of the Court, instituted an aggressive program of abandoning unprofitable lines and restoring profitability to a 3,900-mile midwestern "core" system. The shedding of unprofitable lines, together with the intensive efforts of the Trustee and his staff to improve the railroad's traffic base and reduce costs, resulted in the core system's return to profitability in 1983.

Along with the abandonment and sale of unprofitable lines, the Trustee also pursued a program of selling other excess property. This program, which included the sale in 1981 of approximately 117,000 acres of timber properties owned by the Debtor's subsidiary the Milwaukee Land Company, on very favorable terms to the Estate (approximately $178,000,000 in cash), substantially contributed to the viable restructuring of the Debtor's rail system and the Trustee's present ability to satisfy the Allowable Claims of all creditors.

In April of 1984, pursuant to Court authorization, the Trustee negotiated asset purchase agreements for the sale of the operating rail properties with two competing bidders, the Soo and Chicago and North Western Transportation Company. Both agreements were approved by the Interstate Commerce Commission and returned to the Court for a decision on which should be approved and consummated. The Soo's Asset Purchase Agreement was approved by the Court, and the transactions contemplated by the Asset Purchase Agreement were closed on February 19, 1985.

As a result of these programs and transactions, the asset and debt restructuring of the Debtor is virtually complete. Evaluations of remaining non-rail properties and the planned sale of the remaining rail properties will continue prior to the Consummation Date. However, no further property dispositions or restructuring is required for the discharge of the Debtor from the reorganization proceeding, and the return to the stockholders of a company with substantial cash, other properties and assets, and essentially no debt.

As of the Consummation Date the assets of the Reorganized Company will consist principally of cash, securities and interests in real property. Various plans for the development and implementation of a business plan for the utilization of these assets could be proposed. The Trustee has chosen not to propose any specific business plan for the Reorganized Company in this Plan as he believes this is a matter which is better left to the new management and stockholders of the Reorganized Company.

2.2 Description of Plan

Most of the Estate's obligations to the United States government and other obligations relating to the operation of the core system have been assumed by Soo. The assumed obligations include outstanding indebtedness issued pursuant to Sections 505 and 511 of the Railroad Revitalization and Regulatory Reform Act of 1976, together with the obligations under the Debtor's Series I Redeemable Preference Stock. The remaining Allowable Claims will be paid in cash, to the extent practicable on or before the Consummation Date. No Claim will be satisfied by the issuance of securities.

On the Consummation Date the remaining assets of the Estate will be returned to the Debtor, which will continue in existence as the Reorganized Company. After the Consummation Date the Reorganized Company will continue making cash payments to creditors entitled to payment, out of the Segregated Account.

2.3 Basis for Proposal of Plan

2.3(a) Resources and Application

As of June 30, 1985 the Trustee held approximately $263,000,000 in cash and cash equivalents in the property escrow accounts established by orders of the Court, together with approximately $28,000,000 in tax benefit transfer escrow accounts. In addition the Milwaukee Land Company held as of that date approximately $100,000,000 in cash and cash equivalents. After giving effect to the estimated results of the Estate's operations to July 31, 1985, and assuming no significant sales of properties during that period, approximately $393,000,000 will be available as of July 31, 1985 for payment of Allowable Claims. Allowable Claims as of July 31, 1985 are shown on the attached Exhibit I and are estimated to be approximately $205,000,000. After payment of all Allowable Claims, a significant amount of cash and cash equivalents together with various interests in real properties, including approximately 63,000 acres of real estate and timber properties, will be available for transfer to the Reorganized Company in satisfaction of the stockholders' interests. Assuming no significant property sales subsequent to June 30, 1985, the Trustee also estimates that the Reorganized Company will have available as of the Consummation Date, after giving effect to the expenses of completing the reorganization, a net operating loss carryover in excess of $252,000,000, which may be used to offset future taxable income of the Reorganized Company and its parent Chicago Milwaukee Corporation. These tax benefits, if not utilized, will expire in varying amounts from 1995 through 2000. The Trustee also estimates that the Reorganized Company will have available unused investment tax credits as of the Consummation Date of approximately $24,000,000. These credits will be available to offset future federal income tax liability of the Reorganized Company and Chicago Milwaukee Corporation. These credits will, if not utilized, expire in varying amounts from 1989 through 1998.

2.3(b) Schedule for Distribution to Creditors

Between the Confirmation Date and the proposed Consummation Date, the Trustee will pay Allowable Claims that are not disputed, together with fees and expenses approved in accordance with Section 9.1 below.

III. CLASSIFICATION OF CLAIMS AND STOCKHOLDERS' INTERESTS

3.1 Classification

For the purposes of this Plan, the classification of Claims and the interests of the Debtor's stockholders is as follows:

3.1(a) Class A: *Expenses of Administration:* Class A consists of Allowable Claims (other than Claims in Classes B and D) which are treated as expenses of administration, including Claims of the Debtor's employees under the January 1, 1982 Wage Reduction Agreement, Claims of state and local taxing authorities for taxes, special assessments and other governmental charges relating to the Post-Petition period, and Pre-Petition personal injury claims.

3.1(b) Class B: *Debentures*: Class B consists of Allowable Claims of the holders of the Debtor's Debentures.

3.1(c) Class C: *General Unsecured Claims*: Class C consists of Allowable Claims (other than the Claims in Classes A, B and D) which are unsecured, including Pre-Petition Claims of general trade creditors and Pre-Petition tax Claims, rejected contract claims and traditional labor protection claims.

3.1(d) Class D: *Fees and Expenses*: Class D consists of the fees and expenses approved in accordance with Section 9.1 below.

3.1(e) Class E: *Preferred Stock*: Class E consists of the interests of the holders of the Debtor's Preferred Stock.

3.1(f) Class F: *Common Stock*: Class F consists of the interests of the holders of the Debtor's Common Stock.

IV. DESCRIPTION OF THE REORGANIZED COMPANY

4.1 The Reorganized Company

For convenience, simplicity and economy in carrying out this Plan, the Debtor will continue in existence as the Reorganized Company. Prior to the Consummation Date the Debtor's articles of incorporation will be amended to change its corporate name. This change is required by the Asset Purchase Agreement.

4.2 Capitalization of the Reorganized Company

The Reorganized Company will retain the same equity structure as the present Debtor. The equity structure of the present Debtor is the same as that of the Debtor prior to reorganization, except that the Debtor's Series I Redeemable Preference Shares were cancelled and the underlying obligations assumed by the Soo pursuant to the Asset Purchase Agreement. All capitalized debt and other obligations of the Debtor which were not assumed by the Soo will be discharged or paid prior to the Consummation Date. No new securities will be issued by the Reorganized Company as part of the Plan.

4.3 Assets of the Reorganized Company

As of the Consummation Date the Reorganized Company will be vested with, and will be legal and beneficial owner of, all assets of the Debtor as of that date (subject to the applicable restrictions on assets retained in the Segregated Account and assets retained in the tax benefit transfer escrow referred to in Section 2.3 above), including books, files, records and other papers relating to the reorganization proceeding which are determined by the Trustee to belong to the Debtor. The Reorganized Company's ownership of all its assets will be free and clear of all liens and encumbrance of any kind or character, except as provided in the Plan or by order of the Court.

4.4 Management of the Reorganized Company

The by-laws of the Debtor provide for a number of directors between 9 and 14. Prior to the Consummation Date the Trustee will recommend to the Court the appointment of 9 individuals to serve as directors until the first meeting of shareholders of the Reorganized Company. Prior to the Consummation Date the Trustee will continue to manage the affairs of the Estate, subject to the control of the Court. The Trustee's staff presently consists only of employees of Soo who work at the offices of the Trustee on a contract basis in accordance with the Asset Purchase Agreement. Prior to the Consummation Date, the Trustee anticipates that some permanent employees may be retained. In general, however, the identification and employment of a permanent staff and management will be the responsibility of the Reorganized Company.

V. SATISFACTION OF CLAIMS AND STOCKHOLDERS' INTERESTS

5.1 Treatment of Claims and Interests

For purposes of this Plan, the treatment of Claims and the interests of the Debtor's stockholders is as follows, subject to changes directed or authorized by the Court.

5.1(a) Classes A, B and C: *Creditors' Claims:* The Allowable Claims in Classes A, B and C will be paid in cash, with interest as provided in Section 5.3 and Section 5.4, as soon as practicable after the Confirmation Date.

5.1(b) Class D: *Fees and Expenses:* Fees and expenses approved by the Court as Class D Allowable Claims pursuant to Section 9.1 below will be paid in cash on or before the Consummation Date.

5.1(c) Class E: *Preferred Stock:* The holders of the interests of Class E will continue as holders of the preferred stock of the Reorganized Company. Certificates outstanding as of the Consummation Date will continue to evidence the same number of shares of Preferred Stock of the Reorganized Company.

5.1(d) Class F: *Common Stock:* The holders of the interests in Class F will continue as holders of the common stock of the Reorganized Company. Certificates outstanding as of the Consummation Date will continue to evidence the same number of shares of Common Stock of the Reorganized Company.

5.2 Method of Distribution

After the Confirmation Date the Trustee will begin distributions to creditors. The Trustee will establish a Distribution Date for each class of Claims, which will be the earliest date on which the holders of Allowable Claims in that class are entitled to receive payment under the Plan. Different Distribution Dates may be fixed for different classes of Claims. The Distribution Dates will in no event be later than the Consummation Date.

The Trustee before the Consummation Date and the Reorganized Company after the Consummation Date will distribute the payments to the holders of Allowable Claims under the Plan on and after the applicable Distribution Dates. Distributions to holders whose Claims are finally allowed, settled or adjudicated following the Distribution Date shall take place in the manner set forth in Sections 5.6 and 9.1. Disputes as to the allowability, amount or classification of any Claim shall not delay distributions with respect to undisputed Claims, subject to the provisions of Section 5.5 below. Distributions to creditors will be made against delivery of certificates, properly endorsed with signature guaranteed with respect to Class B Claims, and against appropriate forms of release and satisfaction required by the Trustee with respect to all other Claims.

5.3 Calculation of Interest

Each allowable Claim will be entitled to interest, calculated as provided in this Section and Section 5.4 below. Interest and related charges will be calculated at the rates provided by the Plan from a date a Claim is liquidated until (1) the Distribution Date, in the case of Claims finally allowed, settled or adjudicated prior to the applicable Distribution Date, or (2) the date of payment, in the case of other Claims. The liquidation date shall be deemed the date upon which the principal amount of the Claim is ascertainable from the Trustee's records. With respect to Claims which were liquidated prior to December 19, 1977, the liquidation date shall be deemed December 19, 1977.

5.4 Interest Rate

Interest with respect to Class A and Class C Claims will be calculated in accordance with Section 5.3 above at the rate of seven and one-half percent (7½%) per annum, without compounding, from the date of liquidation to February 19, 1985. From February 20, 1985 to the Distribution Date (in the case of Claims finally allowed, settled or adjudicated prior to the applicable Distribution Date), or to the date of payment (in the case of other Claims) interest will be calculated at the rate of interest currently being earned on the funds of the Estate held in escrow accounts in the name of the Trustee. The current rate of 8.5% shall be applied from February 20 through September 1, 1985. The Trustee, the Debtor or claimants entitled to interest may make application to have this rate altered prospectively for periods beginning after September 1, 1985 in the event the interest then being earned on funds of the Estate should warrant a change.

Interest with respect to Class B Claims will be paid as follows:

(a) Interest at the rate of five percent per annum, without compounding, will be paid on the principal amount of the Debentures beginning on January 1, 1976, and continuing every year or portion of a year thereafter until the Distribution Date for Class B Claims, regardless of whether the Debtor had Available Net Income as that term is used in the Indenture;

(b) Each unpaid annual installment of interest (as set forth in subparagraph (a)) shall itself constitute an Allowable Claim, which shall bear interest at the rates specified in Section 5.4 of the Plan for Class A and C Claims, beginning on the date each installment was due, and continuing every year or portion of a year thereafter until the Distribution Date for Class B Claims; and

(c) Except as provided in subparagraphs (a) and (b), no other interest shall be paid on the principal of the Debentures or on the unpaid installments of interest.

Interest is not applicable to the interests of the holders of the Debtor's Preferred and Common Stock (Class E and Class F Claims).

5.5 Pre-Condition to Distributions Pursuant to the Plan

Except as otherwise provided in agreements made by the Trustee and approved by the Court, no claimant of any class shall be entitled to any distribution pursuant to this Plan unless all claims which the Debtor or the Trustee has against the claimant or any affiliate of the claimant are settled or discharged.

5.6 Claims Undetermined as of Consummation Date

Claims in favor of the Debtor and the Trustee not settled or determined prior to the Consummation Date will be assumed and enforced by the Reorganized Company. Any Allowable Claim against the Debtor or the Trustee which is filed prior to the applicable bar date described in Section 9.1, 10.2 or 11.2 below and included in a class entitled to participation under the Plan which has not been finally settled or adjudicated prior to the Consummation Date shall be entitled to be treated under this Plan as if it had been settled or adjudicated prior to the Consummation Date. The obligations of the Trustee and the Reorganized Company to the holders of these Claims will be limited to the participation provided in the Plan. This Section 5.6 shall not be interpreted as affecting the date of liquidation of a Claim for purposes of calculating the amount of interest payable on that Claim.

5.7 Segregated Account

As of the Consummation Date, cash or cash equivalents in an amount to be determined by the Trustee with the approval of the Court will be deposited in an escrow account (the "Segregated Account") for the purpose of securing and effecting payment of Allowable Claims not paid or settled by that date. Funds in the Segregated Account shall be invested consistent with the directions and limitations to be provided by Court order. Income earned with respect to the funds in the Segregated Account shall be paid to the Reorganized Company.

After the Consummation Date funds in the Segregated Account will be used at the direction of the Reorganized Company only to pay Allowable Claims, and will not be subject to withdrawal for any other purpose without prior approval of the Court. The principal amount of funds to be maintained in the Segregated Account may be modified from time to time upon application to the Court by the Reorganized Company. The Segregated Account will continue in existence until the termination of the right to receive payment under the Plan in accordance with Section 5.8 below. Any funds remaining at that time will be transferred to the Reorganized Company free of the restrictions of the Segregated Account and free and clear of any right, title, and interest of any other person or entity, the escheat or abandoned property laws of any state to the contrary notwithstanding.

5.8 Termination of Right to Receive Payment Under the Plan

The rights of all security holders, creditors and claimants to receive payment under this Plan will terminate five years after the Consummation Date or, as to Claims asserted as of the Consummation Date but not finally settled or adjudicated until after the fourth anniversary of the Consummation Date, one year after the date of final settlement or adjudication. The holders of Allowable Claims who do not deliver certificates, properly endorsed with signature guaranteed, for cancellation with respect to Class B Claims or appropriate forms of release and satisfaction required by the Trustee with respect to all other claims within the time specified in this Section 5.8 will not be entitled to participation under the Plan.

VI. EXECUTORY CONTRACTS

6.1 Rejection and Participation Under the Plan

Prior to the Consummation Date the Trustee will from time to time file with the Court exhibits listing all the executory contracts to be rejected as part of the Plan in accordance with Section 77(b) of the Bankruptcy Act. On the Consummation Date the contracts listed in those exhibits will be rejected effective as of December 19, 1977, the date of the filing of the Debtor's petition for reorganization under Section 77. All executory contracts not listed in the exhibit to be filed with the Court have been assumed by the Soo or other parties pursuant to agreements with the Trustee or will be adopted by the Trustee as of December 19, 1977 and will become obligations of the Reorganized Company, to be performed in accordance with their terms. Claims arising out of rejected executory contracts will be treated as Class C Claims. The Trustee shall give notice prior to or as of the Consummation Date to all parties to rejected contracts in a form prescribed by the Court.

6.2 Discharge of Obligations Under Executory Contracts Assumed by Others

The Trustee, the Debtor and the Reorganized Company shall be discharged from all obligations which have been assumed by others, including the Soo, under agreements with the Trustee entered into during the pendency of the reorganization proceedings, and from all claims based on or arising out of a failure to perform those obligations. Claims with respect to or arising out of those obligations are disallowed and are not included as Claims subject to treatment under the Plan. The holders of these claims shall not receive the notice prescribed in Section 6.1 above with respect to the rejection of executory contracts.

notice
disallowed

VII. VESTING OF ASSETS AND DISCHARGE

7.1 Property to Be Vested Free and Clear of Liens

All property, when conveyed to the Reorganized Company, will be free and clear of all liens and claims against the Debtor and the Trustee, except as otherwise specifically provided in this Plan or by Court order. The Court may require the Trustee, the Debtor, the trustee of any instrument securing any obligation of the Debtor, any mortgagee, and any other proper and necessary parties, to make transfers, conveyances or satisfactions of mortgages in recordable form, and may require the Debtor to join in the transfers, conveyances or satisfactions which are necessary to expedite the Consummation and the vesting of title in the Reorganized Company.

7.2 Discharge of Obligations

All liabilities and obligations of the Trustee and the Debtor, all claims (whether asserted or not) and all liens, security interests and encumbrances on the property of the Debtor, will be discharged as of the Consummation Date, except as expressly provided in this Plan or by order of the Court.

VIII. EXECUTION OF THE PLAN

8.1 Approval and Confirmation of the Plan

After hearings as provided in Section 77(e) of the Bankruptcy Act, held on June 24, 25, 27 and July 12, 1985, the Court on July 12, 1985 entered Order 832 modifying the plan filed by the Trustee on May 1, 1985, approving and confirming the Plan and authorizing the Trustee to proceed with Consummation.

8.2 Consummation Procedure

The Debtor and the Trustee, subject to the supervision of the Court, have the authority to carry out the Plan and the orders of the Court relating to the Plan in accordance with their respective terms, notwithstanding any contrary laws of any state or the decision or order of any state authority. The Trustee will promptly proceed with the Consummation and generally to wind up the reorganization proceedings. The Trustee will have the authority to take all steps necessary or appropriate to Consummation, including provision for staff, disposition of assets of the Estate, and other action considered by the Trustee to be necessary or appropriate to insure that the funds required for Consummation are available when required and that the other assets of the Estate are appropriately managed. The Trustee will determine all forms, instructions, letters of transmittal, and similar instruments used in effecting distributions under the Plan.

8.3 Employment of Agents

In the Consummation of the Plan, the Trustee may employ agents, transfer agents, registrars, trustees, depositories, exchange agents, accountants, attorneys, financial advisors, and others as he considers necessary or appropriate. The Trustee may from time to time delegate to others any power or discretion conferred upon him by the Plan.

8.4 Retention of Jurisdiction by the Court

The Court will retain exclusive jurisdiction under Section 77 of the Bankruptcy Act over the assets dealt with by the Plan, and over any persons appearing in the reorganization proceedings, for the purposes of determining any Claims asserted by or against the Debtor or the Trustee, construing any order in respect of the Plan, carrying out and giving effect to the provisions of the Plan and the orders confirming the Plan, fixing terms and conditions relating to Consummation, and entering the final decree. The Court may cure any defect, supply any omission, or reconcile any inconsistency in the manner and to the extent necessary or expedient in order to carry out the Plan effectively. On the Consummation Date, the reorganization proceedings will be terminated, and a final decree will be entered by the Court pursuant to Section 77(f) of the Bankruptcy Act discharging the Trustee and closing the case, subject to the reservation of jurisdiction by the Court as provided in this Section 8.4.

IX. FEES AND EXPENSES

9.1 Allowance of Fees and Expenses.

After Confirmation the Court will consider applications for allowance of fees and expenses to the Trustee, his staff and counsel, and other parties claiming fees and expenses pursuant to Paragraphs (c)(2) and (c)(12) of Section 77 of the Bankruptcy Act, other than fees and expenses previously approved by the Court, whether or not paid. These applications are required to be filed on or before August 5, 1985 and will be referred to the Special Master previously appointed in these proceedings for hearing beginning on September 4, 1985. The Special Master will report his recommendations to the Court on or before September 30, 1985 and the Court will issue a final order or orders awarding fees and expenses on or before October 31, 1985. Applications submitted under this Section shall reflect requests for allowance of fees through the Consummation Date except that applications by the Trustee and his counsel for fees and expenses from August 1, 1985 through the Consummation Date may be filed with the Court not later than five days prior to the Consummation Date.

X. DISCHARGE OF TRUSTEE

10.1 Discharge as of Consummation Date

As of the Consummation Date the Trustee shall be discharged and his bond released, and he shall be relieved of any further duties and responsibilities (other than the preparation and filing of a final report) in respect of the administration of the property or the conduct of the business and affairs transferred to the Reorganized Company on the Consummation Date.

10.2 Bar Date for Claims Against Trustee

Any claim or action of any nature arising prior to the Confirmation Date against the Trustee individually, arising out of the conduct of his office as Trustee, must be filed with the Court and served upon the Trustee and all parties in interest not later than sixty days after the Confirmation Date or be forever barred. Any such claim which arises after the Confirmation Date but prior to the Consummation Date shall be filed with the Court and served upon the Trustee and the Reorganized Company not later than thirty days after the Consummation Date or be forever barred. Any such claim or action shall be in writing and shall state with particularity the nature of the claim or action and the relief sought. Notice of the bar dates established in this Section 10.2 shall be published in *The Wall Street Journal* (national edition) not later than ten days after the Confirmation Date and not later than ten days prior to the Consummation Date, respectively.

XI. BAR OF CLAIMS AGAINST TRUSTEE AS TRUSTEE, THE DEBTOR OR THE ESTATE

11.1 Bar Dates

In accordance with Orders 201 and 265, certain Pre-Petition Claims which were not filed with the Trustee on or before January 9, 1980 are barred and are not subject to treatment under this Plan. Pre-Petition and Post-Petition Claims against the Trustee in his capacity as Trustee, the Debtor or the Estate which have been filed in a form not satisfactory to the Trustee, or which have not been previously filed and are not barred by Orders 201 or 265, must be filed with the Court and served upon the Trustee not later than 60 days after the Confirmation Date or be forever barred. Any such Claim arising after the Confirmation Date but prior to the Consummation Date must be filed with the Court and served upon the Reorganized Company not later than 30 days after the Consummation Date or be forever barred. Not later than ten days after the Confirmation Date the Trustee shall give notice of the first bar date provided in this Section 11.1 by mail to all claimants whose filings are not satisfactory to the Trustee, and to all persons or entities who the Trustee reasonably believes have a Claim against the Trustee in his capacity as Trustee, the Debtor or the Estate which has not previously been filed and is not barred by Orders 201 and 265. On or before the Consummation Date the Trustee shall give notice of the second bar date established in this Section 11.1 by mail to all persons or entities who the Trustee reasonably believes have a Claim against the Trustee in his capacity as Trustee, the Debtor or the Estate which has not previously been filed and is not barred by Orders 201 and 265 or by the first bar date established in this Section 11.1. Notice of the bar dates established in this Section 11.1 shall be published in *The Wall Street Journal* (national edition) not later than ten days after the Confirmation Date and not later than ten days prior to the Consummation Date, respectively.

11.2 Scope of Bar

The bar dates provided in Section 11.1 apply to all Claims, including Claims for contribution or indemnity existing as of the Confirmation Date and the Consummation Date, respectively. The bar dates provided in Section 11.1, however, do not apply to claims for contribution or indemnity based on facts that are unknown, undisclosed and unasserted as of the Confirmation Date or the Consummation Date, respectively. Claims arising prior to the Consummation Date based on personal injury or death to any person who was a minor at the time of occurrence, as determined under the laws of the State of which he or she was then a resident, may not be asserted against the Reorganized Company unless timely filed by a person having the responsibility over the legal affairs or guardianship of that person. Claims which were the subject of lawsuits filed prior to the Consummation Date but which are not pending on the Consummation Date may not be reasserted subsequent to the Consummation Date, even if dismissal of the lawsuit was without prejudice and the time permitted for refiling has not run. The notices given in accordance with Section 11.1 above shall contain the information set forth in this Section 11.2.

XII. MISCELLANEOUS

12.1 Statement or Explanation Not Warranty or Representation

No statement or explanation contained in this Plan constitutes a warranty or representation or a condition to the binding effect of this Plan upon confirmation by the Court upon any creditor or claimant. No defect or error in this Plan, and no change in the estimates and assumptions underlying the allocation and distribution of payment as outlined in this Plan will release any creditor or claimant from the terms of and obligations under this Plan.

12.2 Notice

Whenever notice is to be given under this Plan, the Court will designate the time within which, the persons to whom, and the form and manner in which the notice will be given. All notices will be given by the Trustee.

12.3 Table of Contents and Section Headings Not Controlling

The table of contents and the section headings contained in this Plan are for convenience only and will not control the meaning or interpretation of this Plan or any of its provisions.

12.4 Exhibit

The following exhibit is attached to and made a part of this Plan.

Exhibit I. Estimated Schedule of Allowable Claims.

Respectfully submitted,

RICHARD B. OGILVIE

Trustee of the Property of the
Chicago, Milwaukee, St. Paul and Pacific
Railroad Company, Debtor.

EXHIBIT I

ESTIMATED SCHEDULE OF ALLOWABLE CLAIMS[1]
(dollar amounts stated in millions)

This schedule contains estimates of the aggregate amounts of Allowable Claims. Actual payments to be made pursuant to Court orders may vary from these estimates. Additionally, this schedule is subject to revision as a consequence of disputed claim settlements and accounts receivable offsets.

Class	Description of Claim		Unaudited Estimated Claim As of 7/31/85
	Expenses of Administration		
A	Provisions for continuing administration and deferred post-petition expenses		$ 7.0
A	Post-petition taxes[2]		5.7
A	Pre-petition personal injury claims[2]		3.5
A	Claims under Wage Reduction Agreement[3]		35.0
	Unsecured Claims		
B	Income Debentures		
	—principal	55.6	
	—interest	35.1	
	—total	90.7	90.7
C	Pre-petition trade creditors		
	—principal	32.9	
	—interest	18.9	
	—total	51.8	51.8
C	Pre-petition taxes[2]		5.4
C	Rejected contract claims		3.0
C	Traditional labor protection claims[2,3]		2.5
	Total Allowable Claims[1]		$204.6

Notes

1. Does not include Class D Claims
2. Exclusive of any interest.
3. Exclusive of any payroll tax obligations, if applicable. In the event of payroll tax liability, such taxes could amount to approximately $7.9 million.

Minute Order Form
(1/85e)

01605

UNITED STATES DISTRICT COURT, NORTHERN DISTRICT OF ILLINOIS, EASTERN DIVISION

Case Number	77 B 8999	Date	FEb. 19, 1985
Name of Assigned Judge	THOMAS R. McMILLEN	Sitting Judge if Other Than Assigned Judge	
Case Title	In Re: Chicago, Milwaukee, St. Paul & Pacific RR Co.		

MOTION: (In the following box (a) indicate the party filing the motion, e.g., plaintiff, defendant, 3d-party plaintiff, and (b) state briefly the nature of the motion being presented.)

DOCKET ENTRY: (The balance of this form is reserved for notations by court staff.)

(1) [X] Judgment is entered as follows (2) [ ] (Other docket entry)

Enter order #809: that the sale and assignment to Soo and SLRCO, in accordance with the APA and this order, of the Trustee's right, title and interest in the Rail Assets are approved and confirmed in all respects.

(3) [ ] Filed motion of (use listing in "MOTION" box above)
(4) [ ] Brief in support of motion due
(5) [ ] Answer brief to motion due ___ Reply to answer brief due ___
(6) [ ] Hearing / Ruling on ___ set for ___ at ___
(7) [ ] Status hearing held / continued to / set for / re-set for ___ at ___
(8) [ ] Pretrial conference held / continued to / set for / re-set for ___ at ___
(9) [ ] Trial set for / re-set for ___ at ___
(10) [ ] Trial / Hearing held and continued to ___ at ___
(11) [ ] This case is dismissed without / with prejudice and without costs / by agreement / pursuant to FRCP 4(j) (failure to serve) / General Rule 21 (want of prosecution) / FRCP 41(a)(1) / FRCP 41(a)(2)
(12) [X] DRAFT For further detail see order on the reverse of / [X] attached to the original minute order form

[ ]	No notices required	number of notices
[ ]	Notices mailed by judge's staff	date mailed notices
[ ]	Notified counsel by telephone	date docketed
[X]	Docketing to mail notices	date mail notices
[X]	Mail CIV-31 form	mailing dpty initials

courtroom deputy's initials: 7

Date/time received in central Clerk's Office

Document #

IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF ILLINOIS
EASTERN DIVISION

In the Matter of	)	
	)	In Proceedings for the Reorganization of a Railroad
CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC RAILROAD COMPANY,	)	
Debtor.	)	No. 77 B 8999 Thomas R. McMillen, Judge

ORDER NO. 409

Upon consideration of the matter of the sale, pursuant to Sections 4 and 5(b) of the Milwaukee Railroad Restructuring Act ("MRRA"), notice having been given to all parties, of the Rail Assets, as defined in and pursuant to an Asset Purchase Agreement dated April 6, 1984, as amended (the "APA"), to be entered into between Richard B. Ogilvie, not personally, but solely as trustee ("Trustee") of the property of the Chicago, Milwaukee, St. Paul and Pacific Railroad Company ("Milwaukee") and the Soo Line Railroad Company, a Minnesota corporation ("Soo"), and SLRCO, Inc., a Minnesota corporation ("SLRCO"), the Court, acting as the Court of Reorganization for the Milwaukee pursuant to Section 77 of the Bankruptcy Act of 1898 and pursuant to Section 4 and Section 5(b) of the MRRA finds and concludes as follows:

1. Soo and SLRCO filed an application with the Interstate Commerce Commission (the "Commission") seeking approval of a purchase of the Rail Assets. In addition, Chicago and North Western Transportation Company ("CNW") filed its application seeking the purchase of essentially similar assets.

2. The Commission rendered its decision on September 26, 1984 with respect to the application of Soo and SLRCO to purchase the assets specified in the APA. That decision, <u>inter alia</u>, approved the application pursuant to Section 11344(b) of the Interstate Commerce Act, Section 5(b) of the MRRA, and Section 77 of the Bankruptcy Act of 1898. The Commission served its further decision with respect to CNW's modified application on January 11, 1985, which decision incorporated certain portions of its September 26, 1984 decision.

3. The Court has ~~heard~~ considered the evidence adduced, heard the arguments of counsel, and the oral and written applications of various parties in interest seeking review of and commenting upon the Commission's September 26, 1984 and January 11, 1985 decisions, including those of the Trustee, Burlington Northern Railroad Company, Chicago Milwaukee Corporation, Escanaba and Lake Superior Railroad Company, First National Bank of Chicago (as Indenture Trustee), Grand Trunk Corporation, Bruce E. Hendry and Mobil Oil Corporation, the

Commission, LaSalle National Bank (as Successor Corporate Trustee), the City of Milwaukee, Wisconsin, CNW, the Chicago, Milwaukee, St. Paul and Pacific Railroad Bond and Debenture Holders Protective Committee (the "Protective Committee"), Railway Labor Executives' Association, Soo, States of Iowa, Minnesota and Wisconsin Departments of Transportation, the United States, United Transportation Union Local No. 528, Wisconsin Power and Light Company, Green Hills Regional Planning Commission, North Dakota Public Service Commission, Seaboard System Railroad, Inc., Harold E. Spencer, Peter N. Todhunter and Richard James Stevens, State of Missouri, South Dakota Department of Transportation, Coalition to Save The Milwaukee and "Certain Employees for the Milwaukee".

4. Section 5(b)(2) of the MRRA empowers this Court to review the order of the Commission entered under that Section only under Sections 706(2)(A), 706(2)(B), 706(2)(C), and 706(2)(D) of title 5 of the United States Code. The Commission has certified to this Court the full record of proceedings before it in connection with the decision of September 26, 1984 and the decision of January 11, 1985. The Court has considered and reviewed the findings and decisions of the Commission filed with this Court, pursuant to the requirements of those sections. The Court has further considered the allegations of error contained in

the petitions for review and comments and has found that the Commission's findings and decisions should be and are approved by this Court, since the findings and decisions were in accordance with law and were not arbitrary, capricious, an abuse of discretion, contrary to constitutional right, power, privilege or immunity, in excess of statutory jurisdiction, authority or limitations, short of statutory right, or without observance of procedure required by law.

5. The Court has ~~heard~~ considered the evidence adduced, heard the arguments of counsel, and the oral and written arguments of various parties in interest expressing a preference for or objecting to the approval of the sale to either the Soo and SLRCO or CNW, including those of the Trustee, Burlington Northern Railroad Company, Chicago Milwaukee Corporation, Escanaba and Lake Superior Railroad Company, First National Bank of Chicago (as Indenture Trustee), Grand Trunk Corporation, Bruce E. Hendry and the Mobil Oil Corporation, LaSalle National Bank (as Successor Corporate Trustee), the City of Milwaukee, Wisconsin, North Dakota Public Service Commission, CNW, the Protective Committee, Railway Labor Executives' Association, Soo, States of Iowa, Minnesota and Wisconsin Departments of Transportation, Stickney Corporation, the United States, United Transportation Union Local No. 528, Wisconsin Power and Light Company, Green Hills Regional Planning Commission, Seaboard System Railroad,

Inc., State of Missouri, South Dakota Department of Transportation, Coalition to Save The Milwaukee and "Certain Employees of the Milwaukee". The Court has considered the Commission's findings with respect to the public interest, the Commission's vote and basis for its preference for the Soo and SLRCO over CNW, the consideration to be paid to the Debtor's estate, the amount of wages to be paid to employees and other relevant matters. The prompt sale of the Rail Assets to Soo and SLRCO for the continued provision of common carrier service in return for the consideration specified in the APA (including the assumption of certain liabilities of the Milwaukee's estate) is in the best interest of the Milwaukee's estate and of ultimate reorganization of the Milwaukee, and is consistent with the public interest. ~~Soo and SLRCO are bona fide purchasers within the~~ meaning of Rule 8-703 of the Bankruptcy Rules of the Supreme ~~Court of the United States.~~

6. The immediate execution by the Trustee of the APA, and the prompt closing of the transactions in the manner and time contemplated by the APA, are in the best interests of the Milwaukee's estate.

7. The Trustee has issued certain Trustee Certificates during the course of these proceedings which were purchased by the United States Department of Transportation ("DOT") and the Federal Financing Bank pursuant to Sections

505 and 511 of the Railroad Revitalization and Regulatory Reform Act of 1976 and Section 7 of the MRRA. The estate also is liable to the DOT under the terms of its Series I Redeemable Preference Shares issued in 1977 prior to the Milwaukee's filing for reorganization. The Trustee's obligations under the above Trustee Certificates and under the Preference Shares will be assumed at closing by Soo and SLRCO in the manner provided in the APA.

8. The purchase of the Rail Assets together with prior purchases approved by this Court constitute the purchase of substantially all of the Milwaukee Railroad for purposes of Section 7(h)(1)(B) of the MRRA (as amended by Section 701(c)(1) of the Staggers Rail Act of 1980), 45 USC §906(h)(1)(B), and all obligations to the United States or any agency or instrumentality of the United States incurred pursuant to Section 7 of the MRRA by the Milwaukee or the Trustee, including Trustee Certificates 1980 A and B are waived and cancelled.

9. The sale of the Rail Assets and the assignment and assumption of the trackage agreements, joint facilities and operating rights over segments of the rail properties now operated by the Trustee are in the public interest (as determined by the Commission and affirmed by this Court) and are in the best interest of the estate as

found by this Court. The assignment and assumption of the trackage agreements, interests in or agreements with respect to joint facilities, leases, operating rights and all other rights and interests of the Trustee being assigned pursuant to the APA will not effect a termination of the Trustee's rights and interests under the contracts, leases and agreements granting those rights and interests, and those rights and interests are [redacted] assignable to Soo and SLRCO in TM accordance with the terms of the APA, and notwithstanding any provisions in any such contracts, leases or agreements to the contrary.

10. Section 5 of the MRRA mandates that the Court require the carrier to provide a fair arrangement at least as protective of the interests of employees as that required under Section 11347 of title 49 of the United States Code. In prior sales of lines of railroad pursuant to Section 5, the Court imposed "Appendix B Conditions" (report of the Special Master dated February 20, 1980) which were found to be as protective as statutorily required and consistent with both the scheme and language of the MRRA by the Court of Appeals for the Seventh Circuit in Matter of Chicago, Milwaukee, St. Paul & Pacific Railroad Company, Consolidated Appeals of Railway Labor Executives' Association, 658 F.2d 1149 (7th Cir. Aug. 17, 1981), cert. den. 455 U.S. 1000 (Mar. 8, 1982).

11. Section 5 of the MRRA does not require that labor protective conditions be imposed with respect to employees of The Milwaukee Motor Transportation Company, and the Court finds that such conditions ~~are unnecessary.~~ should not be imposed.

12. The additional findings and conclusions of law, not inconsistent with the provisions of this Order, made pursuant to Rule 52 by the Court orally on February 8, 1985, are incorporated in this Order by reference and made a part of this Order.

NOW, THEREFORE, IT IS ORDERED, ADJUDGED AND DECREED as follows:

1. That the sale and assignment to Soo and SLRCO, in accordance with the APA and this Order, of the Trustee's right, title and interest in the Rail Assets are approved and confirmed in all respects. The Rail Assets shall, upon conveyance, be free and clear of all liens, security interests, claims and encumbrances, of whatever nature, whenever arising, including without limitation those arising from federal, state and local tax claims or liens, those arising from that certain First Mortgage dated as of January 1, 1944 with Continental Illinois National Bank and Trust Company of Chicago, Indenture Trustee, and the General Mortgage dated as of January 1, 1944 with Harris Trust and Savings Bank, Indenture Trustee, and all mortgages supplemental thereto, except only liens, security interests,

claims and encumbrances created by, or specifically permitted to remain on the Rail Assets pursuant to, the APA.

2. That the Trustee is authorized and directed to execute promptly and deliver to Soo and SLRCO the APA, to consummate promptly the sale as set forth in the APA and to execute and deliver on or as soon as practicable after the Closing Date (as defined in the APA), all deeds, bills of sale, assignments, certificates of title, and other documents, and to take such other actions, as shall be required or appropriate to effectuate the transactions contemplated by the APA, including to the extent necessary under the circumstances as determined by the Trustee, modifications to the APA or the transaction required to result in a fully taxable transaction, so that for federal income tax purposes gain or loss will be fully recognized by the Milwaukee on the consummation of the sale, and that the net operating loss carry forwards and tax credits available to the Milwaukee immediately prior to the closing of the sale will be preserved to the Milwaukee.

3. That the Trustee is authorized and directed to assign to Soo or SLRCO, as appropriate, all of his rights under contracts as provided by the APA.

4. That the Trustee is authorized and directed to assign to Soo or SLRCO, as appropriate and in accordance with the APA, all of the trackage agreements, joint facili-

ties and operating rights necessary for Soo or SLRCO, as the case may be, to operate the Railroad (as defined in the APA).

5. That the Trustee is authorized and directed to assign to Soo or SLRCO, as appropriate, all labor contracts (including collective bargaining agreements) with respect to employees of the Trustee required by the APA to be offered employment by Soo or SLRCO.

6. That Soo and SLRCO, or either of them, assume each of the obligations and liabilities arising under the contracts or agreements assigned by the Trustee in accordance with paragraphs 3, 4 and 5 of this Order. In addition, Soo and SLRCO, or either of them, shall assume the Trustee's obligations under the Wage Deferral Agreement and the last two sentences of Paragraph 2b of the Wage Reduction Agreement, as specified in the APA as modified in the December 4, 1984 letter agreement between the Soo and the Trustee, the obligations of the Trustee under the Trustee Certificates issued to DOT and the Federal Financing Bank pursuant to Sections 505 and 511 of the Railroad Revitalization and Regulatory Reform Act of 1976 or Section 7 of the MRRA (excluding Trustee Certificates 1980 A and B), the obligations with respect to the Series I Redeemable Preference Shares, the obligations of the Trustee with respect to any labor conditions imposed with respect to the transactions contemplated by the APA and other obligations and liabilities

of the Trustee to be assumed by Soo and SLRCO, or either of them, pursuant to the APA. After the Closing (as defined in the APA), all obligations and liabilities of the Trustee to be assumed by Soo or SLRCO in accordance with this Order or the APA and not otherwise discharged shall be the sole obligation of Soo or SLRCO, or both, as the case may be, and the Trustee and the Milwaukee shall be relieved from any and all liabilities in connection with or arising out of such obligations except as expressly may be provided otherwise by the APA, whether occuring after the Closing or arising out of the conveyance or assignment; provided, however, the foregoing shall not impose on Soo or SLRCO any liability or obligation not imposed upon or assumed by them in accordance with the terms of the APA.

7. That all prepetition obligations and debts of the Trustee and Debtor and its subsidiaries to Soo and its subsidiaries are cancelled. In addition, all outstanding debts and obligations of the Trustee and Debtor and any of its subsidiaries arising out of facilities embargoed or abandoned prior to Closing are cancelled.

8. That the sale, transfer and assigment of the Rail Assets is without warranties, representations or guaranties of any kind, expressed or implied, except as specifically stated in the APA.

9. That upon consummation of the transactions contemplated by the APA, all common carrier obligations of the Trustee and Debtor be assumed by Soo and SLRCO, and shall cease as to the Trustee and Debtor.

10. Subject to the agreement of Soo and SLRCO with representatives of employees to labor protection conditions at least as protective as those specified below, the conditions contained in Appendix B to the Report of the Special Master dated February 20, 1980 are adopted for the protection of employees of Soo and Milwaukee Road affected by the transactions contemplated by the APA; Section 4(e) is included therein as specified in Order No. 276B; Appendix B is also modified as provided in Order No. 409A. Notwithstanding the foregoing, no labor protective conditions are imposed with respect to the employees of The Milwaukee Motor Transportation Company.

11. That the Court shall retain jurisdiction over this matter for the purpose of implementing and carrying out the APA and resolving any disputes arising under or with respect to the APA, this Order or the Closing. The ICC shall have such continuing jurisdiction over this transaction as is by law vested in it.

12. That the rights, claims, liens and interests of any creditor of, or claimant against, the Debtor's estate which are not assumed by Soo or SLRCO in accordance with

this Order or adjudicated by this Order as applying to the Rail Assets which are sold, transfered or assigned pursuant to this Order shall be, upon the Closing, transferred from the Rail Assets to the net proceeds of the sale; such net proceeds shall, until further order of this Court, be deposited and retained in the existing trust account bearing the designation "Escrow Agent Account" No. 13-01043-4 at the Continental Illinois National Bank and Trust Company of Chicago and shall be invested pursuant to this Court's Order No. 536 in accordance with instructions from the Trustee or a person designated by him.

13. That following the closing of the sale and pending the earlier of (i) further order of this Court, (ii) the date on which this Order authorizing the sale shall not have been reversed and no further appeal may be taken by any party or (iii) 90 days after the Closing Date, Soo and SLRCO are directed to conduct the operations of the Railroad, (as defined in the APA), and to maintain the Rail Assets, subject to additions and dispositions in the ordinary course, on a basis reasonably designed to account for the operations of the Railroad and the identification of the Rail Assets subsequent to their transfer to Soo and SLRCO.

14. All requests for relief pertaining to the subject matter of this Order not otherwise granted by this Order shall be considered denied.

15. Directions contained in this Order shall be carried out forthwith.

Dated:

ENTER

Thomas R. McMillen
United States District Judge

Feb. 19, 1985

CIV 31
(Rev 5/83)

JUDGMENT IN A CIVIL CASE

United States District Court	DISTRICT: NORTHERN DISTRICT OF ILLINOIS EASTERN DIVISION
CASE TITLE: IN THE MATTER OF THE CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC RAILROAD COMPANY, Debtor	DOCKET NUMBER: 77 B 8999 NAME OF JUDGE OR ~~MAGISTRATE~~: THOMAS R. MC MILLEN

☐ **Jury Verdict.** This action came before the Court and a jury with the judicial officer named above presiding. The issues have been tried and the jury has rendered its verdict.

☒ **Decision by Court.** This action came to ~~trial or~~ hearing before the Court with the judge (~~magistrate~~) named above presiding. The issues have been tried or heard and a decision has been rendered.

IT IS ORDERED AND ADJUDGED

the sale and assignment to Soo and SLRCO, in accordance with the APA and this order, of the Trustee's right, title and interest in the Rail Assets are approved and confirmed in all respects.

CLERK: H. STUART CUNNINGHAM	DATE: Feb. 19, 198?
(BY) DEPUTY CLERK: Kathleen Branch	

IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF ILLINOIS
EASTERN DIVISION

IN THE MATTER OF:	)	In Proceedings for the
	)	Reorganization of a
CHICAGO, MILWAUKEE, ST. PAUL	)	Railroad
and PACIFIC RAILROAD COMPANY,	)	
	)	No. 77 B 8999
Debtor.	)	Thomas R. McMillen, Judge

ORDER NO. 832

Upon consideration of the Trustee's 1985 Plan of Reorganization (the "Plan"), due notice having been given to creditors, stockholders and other parties in interest in accordance with this Court's Order No. 811, the Court, acting as Court of Reorganization for the Debtor pursuant to Section 77 of the Bankruptcy Act of 1898, as amended ("Section 77"), finds and concludes as follows:

1. The Chicago, Milwaukee, St. Paul and Pacific Railroad Company, the Debtor in this proceeding, a Wisconsin corporation, filed on December 19, 1977 its petition to this Court to effect a plan of reorganization under Section 77. A copy of that petition was filed at the same time with the Interstate Commerce Commission (the "Commission"). This Court has jurisdiction over the proceedings pursuant to Section 77.

2. The Court approved the petition as properly filed on December 20, 1977. Stanley E.G. Hillman was appointed trustee of the property of the Debtor on the February 13, 1978. Mr. Hillman was succeeded as Trustee by Richard B. Ogilvie on August 20, 1979. Mr. Hillman from the date of his appointment until August 20, 1979, and Mr. Ogilvie from that date until the present time, have continued in the possession and control of the property and assets of the Debtor and their operation.

3. On March 31, 1983, the Trustee filed with the Court an Amended Plan of Reorganization for the Debtor, which was referred to the Commission by order of this Court. After due notice and hearings, the Commission, in orders served September 26, 1984, and January 11, 1985, approved a modified version of the Trustee's plan.

4. On February 19, 1985, this Court, in Order No. 809, approved the sale of the Debtor's operating rail assets to the Soo Line Railroad Company and its affiliate The Milwaukee Road Inc., formerly SLRCO, Inc. (collectively "Soo") pursuant to the terms of an Asset Purchase Agreement ("APA") between the Trustee and Soo.

5. On April 10, 1985 the Commission, upon petition of the Trustee, issued a decision in which it ruled that

further modifications to the Trustee's Amended Plan need not be considered by the Commission.

6. On May 1, 1985, the Trustee filed with this Court his 1985 Plan of Reorganization for the Debtor (the "Plan"). The Plan recognized the sale of the operating assets to Soo but otherwise incorporated the essential provisions of the plan approved by the Commission. After due notice to creditors, stockholders and other parties in interest was given in accordance with Order No. 811, this Court held hearings, received evidence, and heard the arguments of counsel wishing to be heard on June 24, 25 and 27, 1985 for the purpose of considering approval and confirmation of the Plan.

7. Objections to the Plan and supporting briefs were filed by various parties in interest, including the Debtor and CMC; Soo; The United States of America; Chicago, Milwaukee, St. Paul and Pacific Bond and Debenture Holders Protective Committee ("Committee"); The First National Bank of Chicago (the "Indenture Trustee"); Stickney Corporation ("Stickney"); Pullman Leasing Company, GATX Corporation, Fruit Growers Express and Union Tank Car Company ("Trade Creditors"); Railroads as Creditors ("Interline Railroads"); Chessie System Railroad Co. ("Chessie"); Grand Trunk Western Railroad Co. ("GTW"); Harris Bank ("Harris") jointly with Continental Bank ("Continental"); Messrs. Spencer, Todhunter and Stevens ("Spencer"); Elroy G. Schoeneck; Railway Labor

Executives' Association ("RLEA"); Organization of Minority Vendors, Inc. ("OMVI"); Seaboard System Railroad, Inc. ("Seaboard"); Iowa Interstate Railroad, Inc. ("Iowa Interstate"); certain Counties of the State of Iowa ("Iowa Counties"); J. Howard Brosius; John M. Medvetz; William E. Bromsen, as Trustee for certain preferred stockholders; and Blake H. Schubert, as attorney for unidentified preferred stockholders. Oral objections were propounded at the hearings by the Escanaba and Lake Superior Railroad ("E&LS").

8. At the hearings, the following objections were withdrawn:

(a) the objection of the Debtor and CMC to the provisions in Sections 6.1 of the Plan concerning the procedure for rejection of executory contracts; and

(b) the objection of the Committee which had sought provision in the Plan for lost, stolen or misplaced certificates.

Seaboard withdrew its objections with respect to the provisions in the Plan concerning discharge of claims assumed by Soo and concerning bar dates and notice, while reserving its right to object to the proposed modifications to those provisions that were to be filed with the Court by the Trustee, the Debtor, CMC and Soo.

9. On June 27, 1985 the Trustee, the Debtor, CMC, and certain creditors filed proposed modifications to Sections 5.3 and 5.4 of the Plan, concerning the rates and the method of calculation of interest on Class A and Class C claims. On July 1, 1985 the Trustee, Soo, the Debtor and CMC filed proposed modifications to Sections 5.8, 10.2, 11.1 and 11.2 of the Plan, concerning discharge of claims, bar dates and notice. Due notice was given of these modifications and the time for filing of objections.

10. The Court has considered the certified record of proceedings before the Commission, the Commission's decisions of September 26, 1984, January 11, 1985 and April 10, 1985, the Plan, the objections to the Plan and proposed modifications filed with the Court and propounded orally at the hearing, the briefs filed by various parties, the evidence adduced at the hearings, and the arguments of counsel wishing to be heard.

11. With respect to the Committee's request for discovery with respect to the value of the Debtor's assets, the Court finds:

a. The Committee is not entitled to further discovery pursuant to Bankruptcy Rule 8-705. Rule 8-705 does not apply to proceedings relating to approval or confirmation of a Section 77 plan of reorganization. Such proceedings are governed by Bankruptcy Rule 8-304;

b. Section 77 and Bankruptcy Rule 8-304 do not contemplate _de novo_ hearings before this Court with respect to valuation issues considered or which could have been considered by the Commission, and accordingly there is no justification for allowing further discovery with respect to valuation issues, which could have been raised before the Commission. Ecker v. Western Pacific Railroad Corp., 318 U.S. 448, 473 (1943);

c. Sufficient information with respect to value has been made available to the Committee in the certified record of the proceedings before the Commission, in publicly filed documents, and in interrogatory answers filed by the Trustee. The Court accordingly finds, in the exercise of its discretion to control discovery, that there is no justification for further discovery with respect to the issues raised by the Committee and that the record before this Court with respect to matters as to which discovery is sought is sufficient; and

d. The Court does not see the relevancy or benefit to be gained by the Committee by granting further discovery. The request for discovery and for a continuance of the approval and confirmation hearing is therefore denied.

Bar Dates and Discharge of Claims

12. With respect to the objection of the United States of America seeking provision in the Plan for claims arising out of the government debt assumed by Soo under the APA, the Court rules that Order No. 809 relieved the Trustee from all obligations and liabilities with respect to the government debt assumed by Soo, and that the claims of the United States under that government debt accordingly are not entitled to treatment in the Plan.

13. With respect to the objection of RLEA seeking provision in the Plan for employees' claims under the Wage Deferral Agreement approved in this Court's Order No. 551, the Court finds that Order No. 809 relieved the Trustee from all obligations and liabilities with respect to those claims, which accordingly are not entitled to provision in the Plan.

14. With respect to the oral objection of E&LS seeking treatment under the Plan for claims arising out of trackage rights agreements assigned to Soo under the APA, the Court finds that Order No. 809 relieved the Trustee from all ~~obligations and~~ liability arising out of trackage rights agreements assumed by Soo. ~~and that any claims of E&LS arising out of those obligations are not entitled to treatment under the Plan.~~

15. With respect to OMVI's request for clarification of the treatment of claims asserted by OMVI in an action now pending in the United States District Court for the Northern District of Illinois, Eastern Division, the Court finds that the Trustee's obligations with respect to those claims were assumed by Soo and that Order No. 809 relieved the Trustee from all obligations and liabilities with respect to those claims, which accordingly are not entitled to treatment under the Plan.

16. With respect to the Iowa Counties' objection concerning the treatment of real property tax installments due after February 19, 1985, the Court finds that Order

No. 809 relieved the Trustee from all obligations and liabilities with respect to those taxes to the extent they relate to real property transferred to Soo, and that accordingly those claims are not entitled to treatment under the Plan. With respect to the Iowa Counties' other objections relating to treatment of claims for taxes and special assessments, the Court finds that the Plan adequately provides for those claims, to the extent they have not been assumed by Soo.

17. With respect to Iowa Interstate's objections concerning bar dates for claims against the Trustee in his individual capacity the Court finds that the Plan provides fair and adequate opportunity for Iowa Interstate to assert any claims it may have against the Trustee individually.

18. With respect to Seaboard's objection to the provisions for the discharge of the Trustee upon consummation, the Court finds that this objection is premature and should be denied without prejudice to Seaboard's right to object to discharge at the time discharge is considered by the Court.

19. The proposed modifications filed on July 1, 1985 by the Trustee, Soo, the Debtor and CMC proposed that Section 5.8, the last sentence of Section 10.2 and Section 11.1 and 11.2 of the Plan be modified as follows:

5.8 Termination of Right to Reveive Payment Under the Plan

The rights of all security holders, creditors and claimants to receive payment under this Plan will terminate five years after the Consummation Date or, as to Claims asserted as of the Consummation Date but not finally settled or adjudicated until after the fourth anniversary of the Consummation Date, one year after the date of final settlement or adjudication. The holders of Allowable Claims who do not deliver certificates, properly endorsed with signature guaranteed, for cancellation with respect to Class B Claims or appropriate forms of release and satisfaction required by the Trustee with respect to all other Claims within the time specified in this Section 5.8 will not be entitled to participation under the Plan.

* * *

10.2. Bar Date for Claims Against Trustee

. . . . Notice of the bar dates established in this Section 10.2 shall be published in The Wall Street Journal (national edition) not later than ten days after the Confirmation Date and not later than ten days prior to the Consummation Date, respectively.

* * *

XI. Bar of Claims Against Trustee as Trustee, the Debtor or the Estate

11.1 Bar Dates

In accordance with Orders 201 and 265, certain Pre-Petition Claims which were not filed with the Trustee on or before January 9, 1980 are barred and are not subject to treatment under this Plan. Pre-Petition and Post-Petition Claims against the Trustee in his capacity as Trustee, the Debtor or the Estate which have been filed in a form not satisfactory to the Trustee, or which have not been previously filed and are not barred by Orders 201 or 265, must be filed with the Court and served upon the Trustee not later than 60 days after the Confirmation Date or be forever barred. Any such Claim arising after the Confirmation Date but prior to the Consummation Date must be filed with the Court and served upon the Reorganized Company not later than 30 days after the Consummation Date or be forever barred. Not later than ten days after the Confirmation Date the Trustee shall give notice of the first bar date provided in this Section 11.1 by mail to all claimants whose filings are not satisfactory to the Trustee, and to all persons or entities who the Trustee reasonably believes have a Claim against the Trustee in his capacity as Trustee, the Debtor or the Estate which has not previously been filed and is not barred by Orders 201 and 265. On or before the Consummation Date the Trustee shall give notice of the second bar date established in this Section 11.1 by mail to all persons or entities who the Trustee reasonably believes have a Claim against the Trustee in his capacity as Trustee, the Debtor or the Estate which has not previously been filed and is not barred by Orders 201 and 265 or by the first bar date established in this Section 11.1. Notice of the bar dates established in this Section 11.1 shall be published in The Wall Street Journal (national edition) not later than ten days after the Confirmation Date and not later than ten days prior to the Consummation Date, respectively. 01630

11.2 Scope of Bar

The bar dates provided in Section 11.1 apply to all Claims, including Claims for contribution or indemnity existing as of the Confirmation Date and the Consummation Date, respectively. The bar dates provided in Section 11.1, however, do not apply to claims for contribution or indemnity based on facts that are unknown, undisclosed and unasserted as of the Confirmation Date or the Consummation Date, respectively. Claims arising prior to the Consummation Date based on personal injury or death to any person who was a minor at the time of occurrence, as determined under the laws of the State of which he or she was then a resident, may not be asserted against the Reorganized Company unless timely filed by a person having the responsibility over the legal affairs or guardianship of that person. Claims which were the subject of lawsuits filed prior to the Consummation Date but which are not pending on the Consummation Date may not be reasserted subsequent to the Consummation Date, even if dismissal of the lawsuit was without prejudice and the time permitted for refiling has not run. The notices given in accordance with Section 11.1 above shall contain the information set forth in this Section 11.2.

The Court finds that these modifications represent a fair and equitable settlement between the Trustee, the Debtor, CMC and Soo, and that the Plan provisions, as modified, afford fair and equitable treatment to claimants and the Debtor's stockholders. Accordingly, the Plan should be modified as proposed.

20. With respect to the objections of the Committee and the Indenture Trustee concerning the interest payable on the Debentures, the Court finds for the reasons set forth in the Court's Order No. 831 that the second paragraph of Section 5.4 of the Plan should be modified to read as follows:

> "Interest with respect to Class B Claims will be paid as follows:
>
> (a) Interest at the rate of five percent per annum, without compounding, will be paid on the principal amount of the Debentures beginning on January 1, 1976, and continuing every year or portion of a year thereafter until the Distribution Date for Class B Claims, regardless of whether the Debtor had Available Net Income as that term is used in the Indenture;
>
> (b) Each unpaid annual installment of interest (as set forth in subparagraph (a)) shall itself constitute an Allowable Claim, which shall bear interest at the rates specified in Section 5.4 of the Plan for Class A and C Claims, beginning on the date each installment was due, and continuing every year or portion of a year thereafter until the Distribution Date for Class B Claims; and
>
> (c) Except as provided in subparagraphs (a) and (b), no other interest shall be paid on the principal of the Debentures or on the unpaid installments of interest."

21. With respect to the suggestion of the Debtor and CMC that the original maturity date of the Debentures be reinstated, the Court finds that under Section 77 this Court has the equitable power, in appropriate circumstances, to cure defaults under long-term debt instruments and to

01632

reinstate the original maturity date, but that under the circumstances of this reorganization, that exercise of this power with respect to the Debtor's Debentures is not appropriate.

22. The proposed modifications filed on July 27, 1985 by the Trustee, the Debtor, CMC and certain actively participating creditors proposed that Section 5.3 and the first paragraph of Section 5.4 of the Plan be modified as follows:

5.3 Calculation of Interest

Each allowable Claim will be entitled to interest, calculated as provided in this Section and Section 5.4 below. Interest and related charges will be calculated at the rates provided by the Plan from a date a Claim is liquidated until (1) the Distribution Date, in the case of Claims finally allowed, settled or adjudicated prior to the applicable Distribution Date, or (2) the date of payment, in the case of other Claims. The liquidation date shall be deemed the date upon which the principal amount of the Claim is ascertainable from the Trustee's records. With respect to Claims which were liquidated prior to December 19, 1977, the liquidation date shall be deemed December 19, 1977.

5.4 Interest Rate

Interest with respect to Class A and Class C Claims will be calculated in accordance with Section 5.3 above at the rate of seven and one-half per cent (7-1/2%) per annum, without compounding from the date of liquidation to February 19, 1985. From February 20, 1985 to the Distribution Date (in the case of Claims finally allowed, settled or adjudicated prior to the applicable Distribution Date), or to the date of payment (in the case of other Claims) interest will be calculated at the rate of interest currently being earned on the funds of the estate held in escrow accounts in the name of the Trustee. The current rate of 8.5% shall be applied from February 20 through September 1, 1985. The Trustee, the Debtor or claimants entitled to interest may make application to have this rate altered prospectively for periods beginning after September 1, 1985 in the event the interest then being earned on funds of the estate should warrant a change.

With respect to these proposed modifications, the Court finds that:

a. The proposed modifications represent a fair and equitable settlement between the Trustee, the Debtor, CMC and most of the creditors filing objections to the rates and manner of calculation of interest provided in the Plan. The proposed modifications are the result of extended negotiations conducted by able and experienced counsel for the Debtor, CMC and the creditors who have been most active in these proceedings. In re Penn Central Transportation Co., 354 F. Supp. 710, 715 (E.D.Pa. 1972);

b. It is in the best interests of the Debtor, the Estate, and the creditors to have all these matters immediately and finally resolved. Id.

c. In light of the claims asserted, the prevailing interest rates, the losses suffered by the Estate during the reorganization, the varying statutory rates that apply in states of residence of claimants, and the decision of the Rock Island reorganization court with respect to interest rates, the rates and method of calculation provided in the proposed modifications are fair and equitable to all creditors in Classes A and C.

Accordingly, the Plan should be modified as proposed.

23. With respect to the claims of the United States and the Iowa Counties for interest and penalties on their claims for taxes at rates higher than the interest rates provided for other claims in Classes A and C, the Court finds that penalties are not properly assessable for delay of tax payments occasioned by the reorganization, In re Penn Central Transp. Co., 458 F. Supp. 1234, 1281 (E.D. Pa. 1978); and that the interest rates provided in Sections 5.3 and 5.4 of the Plan, as modified, are fair and equitable and are applicable to both sets of claims.

24. With respect to the objections of Elroy G. Schoeneck seeking interest on Class A personal injury claims at a rate higher than provided for other unsecured creditors, the Court finds that the priority status of the personal injury claimants does not entitle them to higher rates of interest on their claims, and personal injury claimants should accordingly receive interest at the same rates as other unsecured creditors.

25. With respect to the objections of Iowa Interstate seeking pre-judgment interest the Court finds that claims for pre-judgment interest are appropriately resolved as part of the resolution of disputed claims.

26. With respect to the objections of Harris and Continental seeking interest on advances, the Court finds that Harris, Continental and other indenture trustees and committees may assert their claims for interest on advances as part of the procedure provided in Section 9.1 of the Plan for allowance of claims for fees and expenses under Section 77(e). Accordingly, the last two sentences of Section 5.4 of the Plan should be deleted. This does not constitute a finding that they are entitled to interest. With respect to the oral objection of counsel for Stickney concerning the time for filing applications under Section 9.1 of the Plan, the Court finds that the Plan should be amended to provide that such applications may be filed on or before one week after the Trustee files his modified Plan in accordance with ordering paragraph 4 below.

Other Objections of Creditors

27. With respect to the objections of RLEA, MDOT, Iowa Counties and Iowa Interstate concerning the Plan's treatment of disputed claims, the Court finds that:

a. Under Section 77 a plan of reorganization is not required to specify the resolution and treatment of each individual claim against the Estate, but to provide due recognition of the rights of each class of creditors; and

b. The Plan provides fair and adequate means for resolving disputed claims.

28. With respect to the objections of the Committee and Iowa Interstate concerning the adequacy of the Segregated Account to protect claimants whose claims are to be paid by the Reorganized Company, the Court finds that these objections premature, and accordingly should be denied without prejudice to the rights of these claimants to seek appropriate provision for their asserted claims in the Segregated Account at the time it is established.

29. With respect to the request of the Committee and the Interline Railroads that the Plan be submitted to them for voting, the Court finds that the Plan, as modified in accordance with this Order, will provide for cash payment to all creditors of an amount equal to the full value of their claims, and, in accordance with Section 77(e), need not be submitted for voting to any class of creditors.

30. With respect to the objections of preferred stockholders, the Court finds that the Plan provides for no change in the interests of the preferred stockholders, but continues the rights of those stockholders in full force and effect, and accordingly the Plan provides fair and equitable treatment of their interests.

General Findings

31. The Plan, as modified in accordance with this Order, complies with the requirements of Section 77(b).

32. The Plan, as modified,

a. is fair and equitable;

b. affords due recognition to the rights of each class of creditors and stockholders;

c. does not discriminate unfairly in favor of any class of creditors or stockholders;

d. conforms to the requirements of the law regarding the participation of the various classes of creditors and stockholders; and

e. provides for the payment of all costs of administration and all other allowances made, or to be made, by the Court.

33. The approximate amounts to be paid by the Debtor or the Reorganized Company for expenses and fees incident to the reorganization have been fully disclosed to the extent ascertainable, are reasonable, and are within such maximum limits fixed by the Commission. Additional amounts as may be required to be paid out of the Debtor's Estate or by the Reorganized Company for services performed

and expenses and fees incurred incident to the reorganization and the Plan will be subject to the approval of this Court.

34. The Plan, as modified in accordance with this Order, provides for the payment of all claims of the United States for taxes and the United States is not a creditor on any claims for customs duties.

35. The additional findings and conclusions of law, not inconsistent with the provisions of this Order, made pursuant to Rule 52 by the Court orally on June 24, 25 and 27, 1985 are incorporated in this Order by reference and made a part of this Order.

NOW, THEREFORE, IT IS ORDERED, ADJUDGED AND DECREED AS FOLLOWS:

1. The Plan, with the modifications specified in the above findings, and with such other modifications as may be necessary to conform to the above findings, is hereby approved.

2. The Plan, as so modified, is hereby confirmed.

3. Objections to the Plan and the amendments proposed by the Trustee and other parties are allowed to the extent consistent with the above findings and the modifications specified herein. All other objections to the Plan and the proposed modifications are denied.

4. That the Trustee is directed to file with the Court, on or before July 29, 1985, a modified Plan in conformity with this Order.

01638

5. The Trustee is directed to provide notice by mail of the approval and confirmation of the Plan, as modified, to all parties on the Official Service List, and all creditors and stockholders. The Trustee is further ordered to publish, as soon as possible after filing with this Court a modified Plan, notice of the approval and confirmation once in The Wall Street Journal (national edition). The notices provided by mail and in The Wall Street Journal shall also contain notice of the bar dates for claims provided in the Plan.

ENTER

Thomas R. McMillen
United States District Judge

DATED: JUL 12 1985

(1.85c)

01639

UNITED STATES DISTRICT COURT, NORTHERN DISTRICT OF ILLINOIS, EASTERN DIVISION

Case Number	77 B 8999	Date	November 12, 1985
Name of Assigned Judge	MARSHALL	Sitting Judge if Other Than Assigned Judge	

Case Title	IN THE MATTER OF CHICAGO, MILWAUKEE, ST. PAUL and PACIFIC RAILROAD COMPANY, Debtor.

MOTION: (In the following box (a) indicate the party filing the motion, e.g., plaintiff, defendant, 3d-party plaintiff, and (b) state briefly the nature of the motion being presented.)

DOCKET ENTRY: (The balance of this form is reserved for notations by court staff.)

(1) [ ] Judgment is entered as follows; (2) [X] [Other docket entry:]

ENTER ORDER NO. 866: FINAL DECREE

(3) [ ] Filed motion of [use listing in "MOTION" box above]

(4) [ ] Brief in support of motion due____

(5) [ ] Answer brief to motion due____ Reply to answer brief due____

(6) [ ] [ ] Hearing [ ] Ruling on____ set for____ at____

(7) [ ] Status hearing [ ] held [ ] continued to [ ] set for [ ] re-set for ____ at____

(8) [ ] Pretrial conference [ ] held [ ] continued to [ ] set for [ ] re-set for ____ at____

(9) [ ] Trial [ ] set for [ ] re-set for ____ at____

(10) [ ] [ ] Trial [ ] Hearing held and continued to____ at____

(11) [ ] This case is dismissed [ ] without [ ] with prejudice and without costs [ ] by agreement [ ] pursuant to [ ] FRCP 4(j) (failure to serve) [ ] General Rule 21 (want of prosecution) [ ] FRCP 41(a)(1) [ ] FRCP 41(a)(2)

(12) [X] DRAFT [For further detail see order [ ] on the reverse of [X] attached to the original minute order form.]

[ ]	No notices required		number of notices
[ ]	Notices mailed by judge's staff		date typed envelopes
[ ]	Notified counsel by telephone		date docketed
X	Docketing to mail notices		date mld notices
[ ]	Mail CIV-31 form		mailing dpty initials

rld — courtroom deputy's initials

Date/time received in central Clerk's Office

Document #

IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF ILLINOIS
EASTERN DIVISION

IN THE MATTER OF	)	In Proceedings for the Reorganization of a Railroad
CHICAGO, MILWAUKEE, ST. PAUL and PACIFIC RAILROAD COMPANY	)	
Debtor.	)	No. 77 B 8999 Prentice H. Marshall, Judge

ORDER NO. 866

FINAL DECREE

Upon consideration of the Trustee's Motion for Entry of a Final Decree, filed pursuant to the Trustee's Modified 1985 Plan of Reorganization (the "Plan"), due notice having been given to creditors, stockholders and other parties in interest, the Court, acting as a Court of Reorganization for the Debtor pursuant to Section 77 of the Bankruptcy Act of 1898, as amended ("Section 77"), finds and concludes as follows:

1. The Chicago, Milwaukee, St. Paul and Pacific Railroad Company, the Debtor in this proceeding, a Wisconsin corporation, filed on December 19, 1977 its petition to this Court to effect a plan of reorganization under Section 77. A copy of that petition was filed at the same time with the Interstate Commerce Commission (the "Commission"). This Court has jurisdiction over the proceedings pursuant to Section 77.

2. The Court approved the petition as properly filed on December 20, 1977. Stanley E.G. Hillman was appointed trustee of the property of the Debtor on February 13, 1978. Mr. Hillman was succeeded as Trustee by Richard B. Ogilvie on August 29, 1979. Mr. Hillman from the date of his appointment until August 20, 1979, and Mr. Ogilvie from that date until the present time, have continued in the possession and control of the property and assets of the Debtor and their operation.

3. On March 31, 1983, the Trustee filed with the Court an Amended Plan of Reorganization for the Debtor, which was referred to the Commission by order of this Court. After due notice and hearings, the Commission, in orders served September 26, 1984, and January 11, 1985, approved a modified version of the Trustee's plan.

4. On February 19, 1985, this Court, in Order No. 809, approved the sale of the Debtor's operating rail assets to the Soo Line Railroad Company and its affiliate The Milwaukee Road, Inc., formerly SLRCO, Inc. (collectively "Soo") pursuant to the terms of an Asset Purchase Agreement ("APA") between the Trustee and Soo.

5. On April 10, 1985, the Commission, upon petition of the Trustee, issued a decision in which it ruled that further modifications to the Trustee's Amended Plan need not be considered by the Commission.

6. On May 1, 1985, the Trustee filed with this Court his 1985 Plan of Reorganization for the Debtor (the "Plan"). The Plan recognized the sale of the operating assets to Soo but otherwise incorporated the essential provisions of the plan approved by the Commission. After due notice to creditors, stockholders and other parties in interest was given in accordance with Order No. 811, this Court held hearings, received evidence, and heard the arguments of counsel on June 24, 25 and 27, 1985 and on July 12, 1985 for the purpose of considering approval and confirmation of the Plan.

7. On July 12, 1985, this Court entered its Order No. 832 modifying the Plan in certain respects and confirming and approving the Plan as modified.

8. The Plan authorizes and directs the Trustee to proceed with the consummation of the Plan, but provides for the retention of jurisdiction by this Court with respect to the consummation of the Plan, including the entry of a final decree pursuant to Section 77(f) discharging the Trustee and closing the case, except as provided below.

9. The Trustee has substantially completed the consummation of the Plan and it is now appropriate for this Court to enter a Final Decree with respect to certain matters involved in the consummation of the Plan and on the discharge of the Trustee.

NOW, THEREFORE, IT IS ORDERED, ADJUDGED AND DECREED AS FOLLOWS:

1. The "Consummation Date" for purposes of the Plan shall be November 25, 1985.

2. The APA and the Plan require the amendment of the Debtor's articles of incorporation to change its corporate name. The form of amendment to the Debtor's articles of incorportion attached as Exhibit A is approved in all respects. The Trustee is authorized and directed to file that amendment with the appropriate officials in order to effect the change of the Debtor's name. The filing officer in the State of Wisconsin is directed to accept the amendment and to issue the appropriate certificate reflecting the change of the Debtor's name.

3. The following people, who have been recommended by the Trustee as provided in the Plan, are appointed to serve as directors of the Reorganized Company until the first meeting of shareholders of the Reorganized Company:

Jack Nash	Clarence G. Frame
Ezra H. Zilkha	Robert C. Reed
Peter Sharp	Edwin Jacobson
Leon Levy	Daniel R. Murray

Jerold S. Solovy

4. a. The Trustee has recommended and the Court approves the deposit at Consummation Date a total of $225,000,000 million (less the amount paid with respect to Allowable Claims prior to the Consummation Date) in the Segregated Account established by the Plan, and in the Appeal Escrow Account described in paragraph 4b below, with $129,200,898.58 in the Segregated Account and $95,799,101.42 in the Escrow Appeal Account. Five days before the approved Consummation Date the Trustee shall file with this Court and serve on the parties a report showing the amount of Allowable Claims paid prior to Consummation Date and the resulting amount required to be deposited in the Segregated Account. The Segregated Account, but not the Appeal Escrow Account provided for in paragraph 4b, shall be held pursuant to the form of Escrow Agreement attached as Exhibit B. The Escrow Agent shall be the Continental Illinois National Bank and Trust Company of Chicago or such other bank as may be designated from time to time by this Court. The Escrow Agent is instructed to pay money out of the Segregated Account only as provided in the Plan, this Order, or further orders of this Court, and to invest the Segregated Account as provided in paragraph 5.

The Reorganized Company is directed to pay Allowable Claims from the Segregated Account (or from other moneys if no money remains in the Segregated Account), as provided in Section 5.2 of the Plan, except for Class B Claims, which are provided for in paragraph 4b. The Reorganized Company is also directed to pay the reasonable fees of the Escrow Agent for its services with respect to the custody of the Segregated Account.

b. In addition to the Segregated Account provided for in paragraph 4a, there is also established, pursuant to Order 858A, the Appeal Escrow Account of $95,799,101.42 (established 10/16/85), as security for the Class B Claims until disposition of CMC's appeal and the Committee's cross-appeal from Orders 831 and 832. The Appeal Escrow Account shall be held separate and apart from the Segregated Account and shall be subject only to the terms of Order 858A.

5. Amounts in the Segregated Account shall be invested in (i) direct obligations of the United States or obligations of agencies of the United States or obligations which are backed by the full faith and credit of the United States, (ii) certificates of deposit or similar debt obligations of banking institutions, such as bankers' acceptances or repurchase agreements, of commercial banks insured by the Federal Deposit Insurance Corporation, (iii) direct and general obligations of any state which are rated in either of the two highest full rating categories by at least one nationally recognized rating agency, (iv) commercial paper rated not lower than P-1 or P-2 by Moody's Investors Service, Inc., or not lower than A-1 or A-2 by Standard and Poor's

Corporation, or (v) money market funds with fixed principal values and which invest only in instruments with credit ratings equivalent to those specified above. Investments shall be made at the direction of the Reorganized Company. Investment earnings on amounts in the Segregated Account may be paid out to the Reorganized Company as realized.

6. On the Consummation Date all right, title and interest of the Trustee in the property of the Estate shall vest in and become the absolute property of the Reorganized Company, notwithstanding the laws of any state or the decision or order of any state authority to the contrary. Except as otherwise provided in this Order or in the Plan, the Reorganized Company shall take the property free and clear of all claims, rights, demands, interests, liens and encumbrances of every kind and character. The Trustee is authorized and directed to execute and deliver to the Reorganized Company a deed and bill of sale transferring all of the property of the Estate. The form of those instruments shall be determined by the Trustee. All property and funds of the Estate held by persons other than the Trustee shall be delivered or paid over to the Reorganized Company, except (i) the Segregated Account and (ii) escrow accounts pertaining to Tax Benefit Transfer Leases which run in favor of the lessor.

7. Except as provided in this Order or in the Plan, the Debtor, the Trustee in his representative capacity and the Reorganized Company shall be, as of the Consummation Date, released forever from: (i) all obligations, debts, liabilities, claims and causes of action against the Debtor, whether or not filed or presented, whether or not approved, acknowledged or allowed in these proceedings and whether or not provable in bankruptcy, including without limitation all claims assumed or guaranteed by the Debtor or the Trustee or enforceable against the property of the Debtor; (ii) all obligations, debts, liabilities and claims arising from costs and expenses of administration, whether or not filed or presented and whether or not approved, acknowledged or allowed in these proceedings, including without limitation all taxes, assessments, claims and other charges of governmental units or agencies, whenever assessed, accruing prior to the Consummation Date; and (iii) all obligations, debts, liabilities and claims with respect to all bonds, coupons, debentures, notes, certificates, evidences of indebtedness, shares of stock, securities and leases (including interest accrued and dividends declared), without limitation as to their nature and whether made, assumed or guaranteed by the Debtor or the Trustee or enforceable against any of them or the property of any of them.

8. Notwithstanding paragraph 7 above, the Reorganized Company shall be liable and responsible for the payment of Allowable Claims after the Consummation Date as provided in Section 5.2 of the Plan, for those Allowable Claims described in Section 5.6 of the Plan, for its obligations under contracts assumed by the Trustee pursuant to Section 6.1 of the Plan and for obligations of the Trustee arising during the administration of the Estate to the extent that the Trustee is bound by those obligations (including, without limitation, the Trustee's obligations under the APA and Order 809), provided, however, that the Reorganized Company shall not be liable and responsible for claims against the Trustee in his individual capacity and, with respect to such claims, shall not indemnify the Trustee as provided hereinafter. The Reorganized Company shall indemnify the Trustee, his agents, attorneys and employees against any and all expenses (including attorney's fees), costs, fees, liabilities and fines arising out of the matters for which the Reorganized Company shall be liable as set forth in this Paragraph 8 or which pertain to or arise out of the administration of the Estate or the conduct of the reorganization proceedings, except where this Court determines that indemnification is inappropriate.

9. The Court reserves jurisdiction, which shall be exclusive to the extent that under applicable law the Court's jurisdiction is now exclusive:

(a) To consider and act with respect to any Claim against the Debtor or the Trustee included in a class provided for under the Plan or with respect to any contingent claim (which shall not include claims against the Trustee in his individual capacity), asserted but not finally settled or adjudicated prior to the Consummation Date;

(b) To consider and act on any matter over which the Court now has jurisdiction and which has not been adjudicated, discharged or resolved prior to the Consummation Date (including questions and controversies arising under or with respect to the APA and Order 809);

(c) To consider and act on any application for instructions with respect to the Segregated Account, including the distribution of funds from, and any claim upon, the Segregated Account;

(d) To consider and act with respect to the allowance of fees to the Trustee, his staff and counsel, and other parties pursuant to Section 9.1 of the Plan; and

(e) To consider and act upon any other matter as to which the Plan reserves jurisdiction in this Court.

10. The Reorganized Company is authorized and directed to file or record, in each of the jurisdictions in

which it owns real property, a copy of this Order and the deed transferring the property of the Estate to the Reorganized Company. The recording officer in each such jurisdiction shall accept those documents for recording. No tax (including stamp, conveyance, transfer and similar taxes) or other fee shall be imposed with respect to the conveyance of the property of the Estate to the Reorganized Company, except for ordinary and customary fees for the recordation of documents.

11. The APA provides that if all inaccuracies in deeds and other instruments of conveyance from the Trustee to the Soo have not been corrected prior to the consummation of the Plan, the Plan will contain provisions for continued correction of the deeds and other instruments of conveyance. Pursuant to the agreement of the parties to the APA, this Order, rather than the Plan, sets forth provisions for the continued correction of deeds and other instruments of conveyance. The APA also provides for certain adjustments to the purchase price for the Railroad. Soo has claimed that it is entitled to such an adjustment.

The Trustee and the Soo are authorized and directed to continue to negotiate in good faith, prior to the Consummation Date, the settlement of disputes relating to the correction of deeds and other instruments of conveyance and the adjustment of the purchase price under the APA.

If, by the Consummation Date, the Trustee and the Soo have not resolved those disputes, the Reorganized Company and the Soo shall, for 90 days following the Consummation Date, negotiate in good faith to settle the disputes. During the 90 day period, neither the Reorganized Company nor the Soo shall sell, mortgage or encumber real property which immediately prior to the closing of the APA on February 19, 1985 was owned or operated by the Trustee and located within those states in which the Trustee conducted rail operations, without giving prior written notice to the other more than 15 days prior to the proposed action. In the event of disagreement over a proposed action, either party may apply to this Court for appropriate relief. If no settlement of these matters has been completed by the end of that 90 day period, this Court shall hear and resolve the remaining disputes, and retains jurisdiction for that purpose.

12. Except as provided in this Order or the Plan, as of the Consummation Date, the Trustee shall be discharged and shall be relieved of any further duties and responsibilities in respect of the administration of the property or the conduct of the business of the Debtor. The Trustee is forever discharged and released from any liability for any claim in his representative capacity which is barred pursuant to the Plan. His bond shall be released when all claims against him in his individual capacity are finally resolved and satisfied.

13. All persons, firms, corporations and other entities, including without limitation the United States and state and local governmental bodies and agencies ("Entities"), are by this Order perpetually restrained and enjoined from instituting, prosecuting, or pursuing, or attempting to institute, prosecute, or pursue, any suit, action or proceeding ("Action") against the Reorganized Company (or its successors and assigns), or against any of the assets or property of the Reorganized Company (or of its successors and assigns), directly or indirectly, by reason of or on account of any obligation or obligations incurred by the Debtor or by the Trustee, except the obligations imposed upon or required to be assumed by the Reorganized Company by the Plan (including those claims filed pursuant to Section 11.1 of the Plan which are ultimately determined to be Allowable Claims) or this Order. The Actions restrained and enjoined by this Order include, without limitation, those based upon or on account of any right, claim, judgment or interest of any kind or nature in, to, or against the Debtor or any of its assets or properties, or which interfere with, attach, garnish, levy upon, enforce liens against or upon, or in any manner disturb any portion of the property (real or personal) now or in the future belonging to or being in the possession of the Reorganized Company (or its successors and assigns), or which interfere with or take steps to interfere with the

Reorganized Company, its officers, agents and employees, or the conduct of its business.

All Entities are also by this Order restrained and enjoined from prosecuting against the Trustee in his representative capacity or against the Reorganized Company any Action arising out of or based on any act done or omitted to be done in consummating and carrying out the Plan or any order of this Court entered in these proceedings. Notwithstanding any of the foregoing, nothing in this Order shall preclude the further prosecution of any appeal previously noticed and pending as of this date.

14. Except as provided in this Order, all jurisdiction of this Court in or by reason of these proceedings shall be terminated and these proceedings shall be closed effective as of the Consummation Date.

Dated: November 12, 1985

ENTER:

District Judge

CONSENT TO CORPORATE ACTION ON BEHALF OF SHAREHOLDERS OF CHICAGO, MILWAUKEE, ST. PAUL AND PACIFIC RAILROAD COMPANY

The undersigned being the Trustee of the Chicago, Milwaukee, St. Paul and Pacific Railroad Company, a Wisconsin corporation, does hereby, on behalf of the shareholders of the corporation otherwise entitled to vote thereon, and by order of the United States District Court for the Northern District of Illinois, adopt the following resolution as and for a resolution of the shareholders of the corporation as of the date hereof:

> RESOLVED, that the articles of incorporation of Chicago, Milwaukee, St. Paul and Pacific Railroad Company shall be amended to change the name of the corporation to CMC Real Estate Corporation.

Dated: 1985

Richard B. Ogilvie, Trustee of the Chicago, Milwaukee, St. Paul and Pacific Railroad Company

On Behalf of all Shareholders of Chicago, Milwaukee, St. Paul and Pacific Railroad Company

Escrow No. ____________

ESCROW AGREEMENT

To: Continental Illinois National Bank and Trust
Company of Chicago
Trust and Investment Services
Corporate Trust Division, Escrow Section
30 North LaSalle Street - 10th Floor
Chicago, Illinois 60693

The following property is deposited with you by the Trustee ("Trustee") of the Chicago, Milwaukee, St. Paul & Pacific Railroad Company ("Milwaukee Road"), Debtor pursuant to Court Order No. ___

A. The sum of ________________.

B. Copy of Court Order No. ______________. ("Final Decree")

C. Copy of the Trustee's Modified 1985 Plan of Reorganization. ("Plan")

As Escrowee, you are hereby directed to hold, deal with and dispose of the aforesaid property and any other property at any time held by you hereunder in the following manner, subject however, to the terms and conditions hereinafter set forth:

1. You are instructed to invest all monies in this escrow account in only the following instruments with maturities of not more than two years from the date of investment:

(i) direct obligations of the United States or obligations of agencies of the United States or obligations which are backed by the full faith and credit of the United States;

(ii) certificates of deposit or similar debt obligations of banking institutions (including the Escrowee), such as bankers' acceptances or repurchase agreements, of commercial banks insured by the Federal Deposit Insurance Corporation;

(iii) direct and general obligations of any state which are rated in either of the two highest full rating categories by at lease one nationally recognized rating agency;

(iv) commercial paper rated not lower than P-1 or P-2 by Moody's Investors Service, Inc., or not lower than A-1 or A-2 by Standard and Poor's Corporation, or

(v) money market funds with fixed principal values and which invest only in instruments with credit ratings equivalent to those specified above.

Any book entry securities in which the escrowed monies are invested pursuant to this Escrow Agreement shall be held in the Escrowee's custody account with the Federal Reserve Bank of Chicago and maintained separately on the books and records of the Escrowee in the name of the Reorganized Company (as defined in the Plan).

Any certificated securities, certificates of deposit or other certificated items in which the escrowed monies are invested shall be issued as registered in the name of the Escrowee's nominee, and maintained separately on the books and records of the Escrowee in the name of the Reorganized Company.

2. The specific instruments to invest in shall be designated from time to time by the Reorganized Company. All undersigned parties shall receive a copy of the monthly activity statement for the escrow account.

3. Interest shall be accrued and reinvested pursuant to Paragraph 1 above, or may be paid out as realized at the direction of the Reorganized Company.

4. The escrow shall be paid out pursuant to written directions of the Reorganized Company (as defined in the Plan) in accordance with the Plan, the Final Decree and subsequent Reorganization Court orders, including payments directly to the Reorganized Company for reimbursement of payments of Allowable Claims (as defined in the Plan) made by the Reorganized Company.

5. The reasonable expenses and fees, incurred in connection with the escrow account shall be paid by the Reorganized Company.

TERMS AND CONDITIONS

1. Your duties and responsibilities shall be limited to those expressly set forth in these escrow instructions, and you shall not be subject to, nor obliged to

recognize, any other agreement between, or direction or instruction of, any or all of the parties hereto provided, however, these escrow instructions may be amended at any time or times by order of the Reorganization Court.

2. You are authorized, in your sole discretion, to disregard any and all notices or instructions given by any of the undersigned or by any other person, firm or corporation, except only such notices or instructions as are hereinabove provided for or given pursuant to Reorganization Court orders.

3. You shall not be personally liable for any act taken or omitted hereunder if taken or omitted by you in good faith and in the exercise of your own best judgment. You shall also be fully protected in relying upon any written notice, demand, certificate or document which you in good faith believe to be genuine.

4. You shall not be required or have a duty to notify anyone of any payment or maturity under the terms of any instrument deposited hereunder, nor to take any legal action to enforce payment of any check, note or security deposited hereunder. You shall have no liability to pay interest on any money deposited or received hereunder.

5. You shall not be responsible for the sufficiency or accuracy of the form, execution, validity or genuineness of documents or securities now or hereafter deposited hereunder, or of any endorsement thereon, or for any lack of endorsement thereon, or for any description therein, nor shall you be responsible or liable in any respect on account of the identity, authority or rights of the persons executing or delivering or purporting to execute or deliver any such document, security or endorsement or these escrow instructions.

6. Any notices which you are required or desire to give hereunder to any of the undersigned shall be in writing and may be given by mailing the same to the address indicated below opposite the signature of such undersigned (or to such other address as said undersigned may have theretofore substituted therefor by written notification to you), by United States mail, postage prepaid. For all purposes hereof any notice so mailed shall be as effectual as though served upon the person of the undersigned to whom it was mailed at the time it is deposited in the United States mail by you whether or not such undersigned thereafter actually receives such notice. Notices to you shall be in writing and shall not be deemed to be given until actually received by your trust department employee or

officer who administers this escrow. Whenever under the terms hereof the time for giving a notice or performing an act falls upon a Saturday, Sunday, or holiday, such time shall be extended to the next business day.

7. If you believe it to be reasonably necessary to consult with counsel concerning any of your duties in connection with this escrow, or in case you become involved in litigation on account of being escrowee hereunder or on account of having received property subject hereto, then in either case, your costs, expenses, and reasonable attorney's fees shall be paid by the Reorganized Company.

8. It is understood that you reserve the right to resign as Escrowee at any time by giving written notice of your resignation, specifying the effective date thereof, to the undersigned. Within 30 days after receiving the aforesaid notice, the undersigned agree to appoint a successor Escrowee to which you may upon Reorganization Court approval distribute the property then held hereunder, less your fees, costs and expenses. If a successor Escrowee has not been appointed and has not accepted such appointment by the end of the 30-day period, you may apply to the Reorganization Court for the appointment of a successor Escrowee, and the costs, expenses and reasonable attorneys' fees which you incur in connection with such a proceeding shall be paid by the Reorganized Company.

9. This escrow agreement shall be construed, enforced, and administered in accordance with the laws of the State of Illinois.

10. The undersigned Escrowee hereby acknowledges receipt of the property described in the above Escrow Agreement and agrees to hold, deal with and dispose of said property and other property at any time held by it hereunder in accordance with the foregoing Escrow Agreement.

11. Executed this 31st day of October, 1985, at Chicago, Illinois.

Parties to Escrow	Addresses
Richard B. Ogilvie, Trustee of the Chicago, Milwaukee, St. Paul and Pacific Railroad (Debtor)	547 W. Jackson Avenue Suite 1510 Chicago, Illinois 60606

____

Continental Illinois National Bank
and Trust Company of Chicago,
Escrowee

By________________________________

Executed in ____ copies.

SCHEDULE I

1. Acceptance Fee - $5,000.00

2. Annual Fee - $5,000.00 per year payable in arrears on November 1, 1986 and each subsequent November 1 during the term of escrow.

3. Transaction Fees and Out-of-Pocket Charges - in accordance with the printed schedule of fees attached to this Schedule I, as that schedule may be modified by the excrowee during the term of this escrow consistent with the escrowee's published fees.

EXHIBIT E

DOCUMENTS RELATING TO
TWIN CITY DISPOSAL

01662

V

TO: Joe Crea

FROM: Kent Schonberger

DATE: February 27, 1969

SUBJECT: Further information relative to Milwaukee Railroad refuse being dumped at Pig's Eye Landfill

Mr. Johnson from the Milwaukee Railroad called me on February 25, 1969, the same day that I received your memo with regard to the circumstances about which he was asking.

I told Mr. Johnson, as confirmed in your note, that we could see no reason for having hold ups or delays in connection with their trucks dumping at Pig's Eye and also that we would not have any objection to them bringing in some lumber, especially if this is being deposited in areas which the Milwaukee Railroad gave us for dump operations.

Insofar as bringing the location in at a gate or driveway off their property, Mr. Johnson feels this is not necessary inasmuch as they would come through the normal Pig's Eye access road. This way their own identified truck would be coming in and I'm sure other than for record keeping purposes, you would let it in then without any charge for such dumping on the earlier stated basis of about four loads per day.

Mr. Johnson also told me that they often hire a private contractor, possibly Twin City Waste Disposal, to haul some material from an area further down toward their humping yards and that this amounts to about nine 17 yard compactor loads per month, or an average then of about one every second or third day. He told me that at the present time the firm hauling this apparently is paying the entrance fee and in turn the Railroad is being billed this amount and he asked whether or not an arrangement could be made for the Railroad to be rebated that money. I explained that any type of rebate would be an almost impossible thing once the money was within the City financial umbrella, but that if we had some completely clear and positive means of identifying who was bringing the material and that only those loads which came from the Milwaukee Railroad would be allowed in, arrangements could likely be made between you, Mr. Johnson and the firm doing the hauling for a positive means of identification, perhaps by some special tickets, signed slips or the like, we would allow the private firm trucks hauling from the Milwaukee Yard properties only to come into Pig's Eye also via the normal roadways and gate at no charge. Mr. Johnson will look further into this matter and be in further contact with you or me. This for your information.

KS

KS:ma
DEN

EXHIBIT F

MAP SHOWING USES ON THE RAILROAD PARCEL

01664

EXHIBIT F